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JOURNAL OF CHEMICAL EDUCATION

for March, 1938

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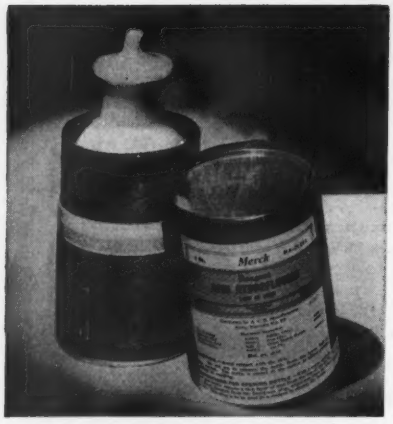
The CHEMISTRY of the GIANT TELESCOPE



A world, yet unseen and unknown, awaits the completion of the giant 200-inch telescope, being erected on Mount Palomar, California. Scientists anxiously await the moment when the huge "eye" can be focused on distant planets to determine, among other things, what types of life, if any, exist in the far reaches of the universe.

The task of constructing such a telescope, of grinding and polishing the enormous mirror to a degree of perfection never before attained, is in itself amazing. But what of the research chemists who struggled long hours to determine the standards of materials to be used in the construction of this scientific instrument?

The standards set by the laboratory chemist for such vital research work are necessarily exacting. So, too, are the standards established for the manufacture of Merck Reagent Chemicals which are used by exacting chemists.

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CARL ADOLPHE WÜRTZ (1817–1884)

Würtz discovered the glycols and did important work in the field of alkylamines, ethylenoxyd, cholin, the aldehydpolymerisates and the higher hydrocarbons. He studied the transformation of hydrocarbons into alcohols, and of aromatic sulfonic acids into phenols. His literary activity was important. (*Dr. E. Berl of Carnegie Institute of Technology lent the photograph which is reproduced here.*)

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EDITOR'S OUTLOOK

HOW NOT TO GO ABOUT SEEKING JOBS AND INFLUENCING PERSONNEL MEN. An accumulation of first-hand observations, of documentary evidence, and of oral anecdote persuades us that applicants for positions in general are often either ill-advised or so ambiguously advised that they deplorably misconstrue the advice they have received.

There is much poor advice on the subject of letters of application. Nearly all of it counsels the applicant to "be different"—to write a letter that stands out from competitive applications, and so focuses the attention of the prospective employer, or his personnel man. That this may be construed in such a way as to constitute bad advice is perhaps most readily illustrated by analysis of a hypothetical lot of applications.

Among such a lot there will be a certain proportion that, as far as the eye can distinguish, are absolutely artless. The applicants have apparently sat down and dashed off what first came into their heads, without selection, arrangement, or thought of effective presentation. All, or nearly all, of these are scheduled for the "round file."

Another proportion will reek of the gingerbread art that is far worse than no art at all. These letters will be couched in a succession of horrible and stilted clichés which are evidently regarded by the writers as constituting the idiom of modern business. If, perchance, one of the writers does push aside for a moment his rubber stamp collection and pick up his pen, the result is what he, doubtless, seriously regards as fine writing, and what the rhetoricians sardonically call by the same name. More work for the janitor.

The next class includes examples of neo-primitive imitative art. The writers have read articles or books on how to apply for a position. They have not stopped to consider that the authors of some of these books have never made successful application for a position in their lives, but have only sold gullible people the idea that they know how it should be done. They have not sensed the fact that the authors of some of these articles should have taken for their title, "the kind of line I fall for." The applications are copies, with appropriate changes in wording, sometimes none too deftly achieved, of textbook examples. The writers show that they have given thought (if thought it can be called) to their applications, but they also show an uncritical attitude and a lack of initiative and imagination. Those are not disqualifications for all positions, but they are disqualifications for a majority of the positions for which a prospective chemist is likely to apply.

Then there is the good-idea-gone-wrong type of letter. The writer has grasped the idea that his letter should be neither stereotyped nor imitative, and has then run off at a tangent. He puts into reverse the farmer's method of finding a strayed cow. He considers how any other applicant might do it, and then tries to conceive a manner in which no other applicant could do. Obviously, this method leads to infinite variations in outcome, but to the discerning eye they are all as definitely typed as those of the cliché and copybook schools. One definite sub-class of this type adopts shock tactics. The writer begins with a first sentence calculated to unhinge the jaw, bug the eyes, and accelerate the pulse of the prospective employer. The follow-up is usually staccato and full of punch. This kind of letter sometimes hooks suckers—but who wants to work for a sucker? Sometimes it even gets the attention of a sensible man who perceives the method behind the madness, and is optimistic enough to hope that he can kick some of the damned nonsense out of that kid and make something of him.

Finally, there is the type of application employing the art that conceals art. (This is the kind of line we fall for.) It is individual, not because it strains to "be different," but because the writer has written naturally and sincerely. It is as characteristic of him as his thumb-print. It gives concisely and clearly the information that a reasonable man would need upon which to base an opinion as to his acceptability. If scholastic records or a bibliography of publications, or other statistical data are pertinent, these are enclosed or offered upon request—not transcribed into the letter. Aside from the revelation of personality made by his application the writer has little to say, and that little is restrained without teetering backward into hypocritical false modesty. His references will take care of the personality question. The general tone is self-confident and self-respecting, without being cocky or belligerent. And when the writer gets done, he stops.

So shall we.

RICHARD WATSON, EIGHTEENTH CENTURY CHEMIST *and* CLERGYMAN*

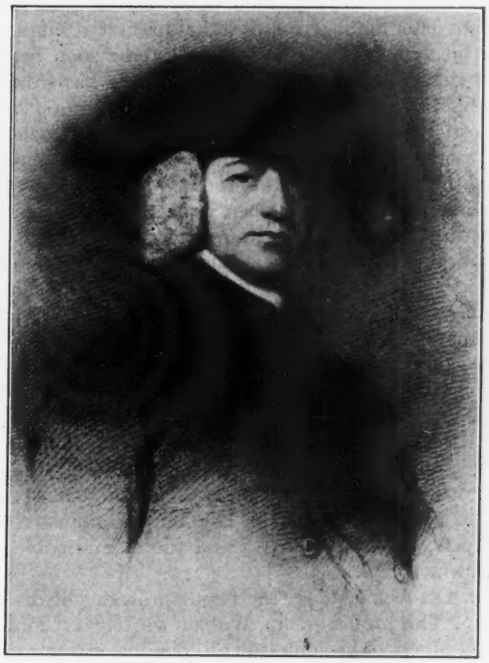
VIRGINIA BARTOW

University of Illinois, Urbana, Illinois

CERTAINLY, everyone gains a great deal of pleasure from the cultivation of new friends. By judicious reading, personalities of bygone years may be added to those of the present. There is no more delightful way to acquaint oneself with various individuals who have played their part in chemical history than to enter an old book shop and browse among the older chemical books. On a jaunt through England, the possibilities of meeting a lesser figure, but by no means an unimportant one in the chemical field, are excellent. Such a man was Richard Watson, one-time professor of chemistry at Cambridge, political writer and Bishop of Llandaff in Wales. His acquaintance was made through five volumes of his writings found in a book store in Chester.

Watson was born in August, 1737, the younger son of Thomas Watson, a clergyman and master of a grammar school of Heversham, Westmoreland. The father was of that class of English people who were small property owners, an honest group who had simple habits. It was at Heversham that the son received his early education which was followed by study at Trinity College, Cambridge, where he was sizar in 1754. Tradition claimed that he appeared at Cambridge in "blue worsted stockings and a coarse mottled coat."

It is to his credit that Watson, prepared in a less thorough way than those who went to college from Eton, made himself master of what he had not been taught. He trained himself not only to write Latin, but to speak it. In his autobiography he wrote, "It cost me more pains to remember whether a syllable was long or short than it would have done to comprehend a whole section of Newton's 'Principia.'" To show his earnest application to his work while he was at Cambridge, Watson said of himself that for two years and seven months he never left the college for one whole day. While he did have some social pleasures, nevertheless, when he returned to his room at one or two in the morning after a jolly evening and observed the light in the chamber of one of his own standing, it never failed to excite his jealousy so that the next day was one of hard study. He went without his dinner a hundred times to finish his assignments. He learned to concentrate while others thought that he was lounging by himself or taking aimless walks. This was when he was assimilating his knowledge until it was his and "in his head without book, pen or paper." In this way he mastered a large portion of such authors as Euclid and Newton.



RICHARD WATSON

CHURCHMAN AND SCIENTIFIC INVESTIGATOR, THIS ENGLISHMAN INFLUENCED MANY BY HIS FIVE VOLUMES OF CHEMICAL ESSAYS AS WELL AS BY HIS THEOLOGICAL TRACTS. FOR A LONG TIME THE CHEMICAL ESSAYS WERE WIDELY READ AND THEY ARE STILL INTERESTING TODAY. HOWEVER, WATSON LAID ASIDE SCIENTIFIC PURSUITS IN HIS LATER YEARS FOR RELIGIOUS AND INFLUENTIAL POLITICAL ENDEAVOR

From the first, it was evident that he was a very clever student. He won the favor of the master and quickly obtained his B.A. in 1759 as second wrangler.

* Presented before the joint meeting of the Divisions of History of Chemistry and Chemical Education at the Midwest Regional Meeting of the A. C. S., Omaha, Nebraska, April 30, 1937.

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He reported that his examination entitled him to first place, but the talk provoked in his favor by the award to another did him more service subsequently than the position of senior wrangler. As partial recompense for the supposed injustice, he was made a fellow the next year, obtained his M.A. and became a moderator two years later. In 1764 the professor of chemistry died, and Watson's reputation was sufficient to win his unanimous election to the chair. Candidly, he himself remarked that he "knew nothing of chemistry, had never read a syllable on the subject, nor seen a single experiment, but [that he] was tired of mathematics and natural philosophy and wanted to try his strength in new pursuits."

To begin his study of chemistry, Watson sent to Paris for a demonstrator who could teach him. Following the arrival of this man, he studied constantly in the laboratory for fourteen months in order to prepare himself to lecture. An explosion, which shattered his room, did not deter him. He agreed that his first attempts before an audience were awkward, but he soon became very dexterous so that his lecture room was crowded. Contemporary accounts picture Watson as a man of majestic commanding figure, a terrific countenance, a deep sonorous voice and originality and boldness which filled the seats of the lecture room. It was not long before he printed his first paper, written in Latin, entitled "Institutionum Chemicarum Paris Metallurgica" at Cambridge in 1768. This and all of his subsequent papers in the *Philosophical Transactions of the Royal Society*, of which he was unanimously elected a member February 2, 1769, were subsequently gathered into the five volumes of the Chemical Essays. The chair of chemistry was unendowed when Watson first held it. Through a friend, John Luther, and the Second Marquis of Rockingham and Newcastle, Watson managed to get £100 from the Crown while he was professor. Meanwhile, he began the study of anatomy and practical dissection. One cannot help but be impressed with the persistence of the man and the indefatigable zeal with which he worked.

On October 5, 1771, the regius professor of divinity died. This professorship, Watson wrote, was "long the secret object of his ambition although he was not qualified as he had no degree in divinity." He obtained the king's mandate which allowed him to be created a Doctor of Divinity, the day before the examinations were held for the applicants for the divinity chair. This was accomplished "by hard riding and some adroitness." By the end of October, another of the unanimous elections by which Watson gained his objectives took place, and he assumed office the middle of November. With the chair, he inherited one or two rectories. The preferments brought him some income. On entering upon his new position, he wrote that "he knew as much of divinity as could be reasonably expected of a man whose course of studies had been directed to and whose time had been fully occupied with other pursuits."

Once again our friend, now Dr. Watson, applied himself to the learning of a new profession. Not having the inclination toward systematic and historical theology, he neglected it in preference to an intensive study of the Bible itself. We see from his writings that he had implicit faith in the Holy Script, particularly emphasizing the New Testament as the last court of authority. Watson continued to devote some time to chemistry until he felt obliged to cease because he regarded his study of the subject as not altogether becoming a clergyman. Then he burned all his scientific notes and left the subject forever. One cannot help but speculate upon what was lost by this deliberate conflagration.

As a clergyman, Watson continued to show the same independence of thought and originality that he displayed as an experimenter. He was expected to join the Society for the Propagation of the Gospel, but he declined to contribute to its support, since he believed that the chief aim of the organization was to proselyte the dissenters into the Episcopacy, rather than to convert the heathen into Christianity. He refused to sign a petition to relieve the clergy from subscription. He did support the cause of the church by seeing that a letter was prepared and in the hands of all the members of the House of Commons, denouncing any other belief than that of the scriptures. Such was his ability that he obtained, in addition to his first, another rectory in the diocese of St. Asaph and a prebend at Ely. Following this he became archdeacon at Ely and acquired two more rectories.

In 1782 the See of Llandaff was left vacant. With the help of the Dukes of Grafton and Rutland, who had befriended him before, and Lord Shelbourne, the appointment was obtained for Watson. It was the poorest see in Britain, so that Watson retained his other preferments, with the exception of the post of archdeacon. It gave him the fair sum, all told, of £2200 per year. In 1786, his friend, Luther, died and left him £20,500 which enabled him to live more comfortably and acquire a deputy to fill his chair of divinity at the university. By this time the bishop had married and had six children, so that he was glad to have his financial resources in a more satisfactory condition. As bishop in Wales, Watson had reached his highest post, but he struggled vainly, and, in the end, bitterly to establish himself in a better see. Fortune at last failed to favor him, so that in a few years he retired to a place in Westmoreland where he lived, doing little that might have been considered his church duty. Only triennial visits were paid to his bishopric. Sir William Pope, the present professor of chemistry at Cambridge, told me that Watson only preached a single sermon in Wales and that on the general theme of the decline of the clergy, due to the fact that the incumbents of the church offices failed to carry out their obligations.

On his place in Westmoreland, the tireless investigator turned to the study of methods for the improvement of waste land. The Society of Arts gave him a premium for a paper on the subject. The Board of Agriculture presented him with a medal. Other honors came to him later in life; membership in the Massachusetts Historical Society, although he was not an his-

torian; connections with the Manchester Literary and Philosophical Society of which he was an honorary member; Fellow of the American Society of Arts and Sciences, and vice-president of the Society for the Suppression of Vice. In 1809 he had a slight paralytic stroke which was followed by the more serious crippling of his right hand two years later. Despairing of finishing some theological tracts when this misfortune occurred, he burned his papers on divinity just as he had burned his chemical notes years before. Watson died in 1816 and was buried in Windermere church.

His last years were filled with writing of papers and speeches in which he expressed his religious and political ideas. In politics Watson was a Whig, in opposition to the king, who was definitely on the Tory side. Watson would have liked to see a coalition government, but the Whigs became so unpopular that it was not possible. The Duke of Rutland remarked that the Bishop of Llandaff was an enemy to the increase of the influence of the crown, because Watson was afraid that it would undermine the constitution. His attitude was not unjustifiable, due to the enormous increase of the national debt. There is little question that his liberal tendencies incurred the disfavor of the court, which was in a large measure responsible for his lack of preferment at the end of his life. A part of his "Address to the People of Great Britain" reads as follows, "I am neither the friend or enemy of any party of the state and am so far an impractical man, that on all public questions of importance, I will follow the dictates of my own individual judgment." In 1776, he had the temerity to preach a sermon in which he vindicated the principles of revolution. In the light of the happenings in the American colonies this displeased the king. He also opposed the king in supporting the Prince of Wales' right to become Regent when the king was ill. Even though there were many who agreed that such sentiments should be preached at St. James once in four weeks, it was not a politic thing to do.

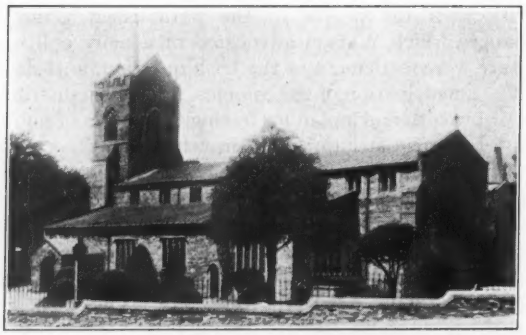
The theological tracts which Watson wrote were often designed to counteract attacks upon Christianity. One was a "Defence of Christianity," addressed to Gibbon, author of "The History of the Decline and Fall of the Roman Empire." Gibbon had maligned the virtues of the early Christians and aroused the ire of the clergy. Another was an "Apology for the Bible" which was addressed to Thomas Paine to "dispel the clouds in which he impiously conceived Christians had for so many years enveloped the world." Watson was said not to have actually read "The Age of Reason," by Paine, but the words of the Bishop that "one thousand such Paines are as the dust of the balance when weighed against Newton" were widely read by thinkers of his period. In this way Watson's tract materially lessened Paine's influence. These writings were not intolerent because Watson was only too willing to let others believe what they wished provided they adhered in spirit to the teachings of the Bible. For a clergyman of the Church of England to say of the Duke of Grafton who was a Unitarian at that time, "If any one thinks that a Unitarian is not a Christian, I plainly say, without being myself a Unitarian, that I think otherwise" was quite unorthodox and emphasizes Watson's lack of religious bigotry. When one reads these two of his more important theological works, he is impressed also with the forceful way in which the arguments are presented.

Other writings urged the revision of the liturgy; the redistribution of the church revenues to make them more equitable and the building of twenty new churches in London where there would be free sittings for the poor. Watson published a compilation of twenty-four theological tracts in six volumes which he thought every young man fitting himself for the ministry should study. Many of these tracts were written by Dissenters, which made no difference to the Bishop as long as he considered them sound in theory. Unfortunately, their inclusion was another factor which decreased his popularity with the people of the Established Church. Changes which Watson advocated of a more political nature were settlement of the Irish question, anti-slave trade, emancipation of the colonies, more even distribution of wealth and a plan for freeing the nation of public debt by one patriotic effort in which all the people should pay an apportioned sum. Suppression of vice, he thought, should not be leveled against the poor, but, rather, against the well-to-do, as it was their duty to set good examples to the lower classes.

It is easy to see that Bishop Watson was a man of strong character. It is interesting to speculate regarding the position he would be taking if he could reappear at the present day. However, contemporary writers have given their opinion of the man, as they wrote voluminously in criticism of his Memoirs. No person of his versatility, ambition, and power of directing his merits toward his own success could have failed to have had staunch friends and equally fervent foes. One could scarcely find more complimentary passages than those of the reviewers in the *Gentleman's Magazine* and *Edinburgh Review*. Turning to a third account of his autobiography in the *Quarterly Journal*, we find the writer convinced that he is attacking the worst miscreant. The same events which friends considered signs of genius were pictured as the deeds of a wily, scheming man.

His enemies accused him of cultivating as private pupils, those who could do him favors and cited Mr. Luther who left him such a fine legacy. Of all diocesans he was the most remiss. While he held the poorest bishopric in the kingdom, because he did not rightfully relinquish the fourteen places of preferment which he had gathered to himself, he was the richest bishop on the bench. His Memoirs showed a total lack of delicacy in speaking his opinions, since he always mentioned the names of those he criticized. His loss of favor and prestige, giving rise to his incessant clamours of disappointment, was laid to his self-interest, thwarted by temper and presumption. He was compared to Swift who was not really independent in the minds of his accusers, but rather defiant as the result of his disappointed ambition. If he thought that the Bishops who opposed him were not his mental equals and could not

understand him, it was because his insufferable and unconquerable egotism was the result of long addiction to mathematical pursuits that incapacitated the mind from weighing various degrees of moral evidence. He was blamed for not coming to the aid of Priestley after the Birmingham riots for fear that he would be criticized, although he professed liberal views. He was given £1000 for his "Apology for the Bible" which he "intended" to use for a charitable edifice, but his enemies said he did not really plan to do anything but use it for his own selfish interests. To conclude the unfortunate picture, Watson's addresses were merely "sounding inanity and dexterous sophistry" and his Memoirs were "the result of twenty years of collecting and concentrating intellectual poison."



WINDERMERE CHURCH

THERE IS A MONUMENT TO THE MEMORY OF BISHOP WATSON IN THE SOUTH CHAPEL. HE IS BURIED IN THE CHURCHYARD

The favorable view pictured him as liberal and tolerant, contributing valuable literary performances, showing firm independence of character, gaining honor through the force of his own talents and industry. His attempts at reform were definite but polite, couched in mild language and a direct contrast to the furious intolerance that was laid at Priestley's door. The followers of Priestley, in turn, thought that the less vehement attitude of Watson indicated insincerity. He was, in the age in which he lived, the one dignitary of the church who did not walk the road to preferment through sycophancy and servility to the court. He was by far the brightest ornament of the English Episcopal bench.

The Chemical Essays were written in the years between 1768 and 1781. In the later editions, of which there were as many as seven by 1800, the forty-three titles were gathered into five small volumes, designed to be read by the general public. In fact, Bishop Watson had no intention of writing a text, since he says in his preface, "The subjects of the following essays have been chosen, not so much with a view of giving a system of chemistry to the world, as with the humbler design of conveying in a popular way, a general kind of knowledge to persons not much versed in chemical inquires." He continued by apologizing to the chemists for the "disgusting minuteness" with which he treated some things and because he passed over some "interesting questions." He apologized to the divines for stealing a few hours from the study of his profession to cultivate natural philosophy with the excuse that "the books of Nature and Revelations equally elevate our conceptions and incite our piety."

The essays were also written in the hope that some of the young men in Britain could see what an interesting object of study chemistry might be, because of its utility, and abstain from wandering abroad in vain and idle pursuits after their years at the university. This remark reminds one of the occasional comment that Liebig's laboratory, a little later, furnished a place where young men of the upper classes could find work for both minds and hands without losing prestige.

The original essay was written in Latin. Another was actually the outline of the course of chemistry as Watson gave the lectures at Cambridge, offering an interesting contrast to the so-called "cultural courses" in chemistry today. The remainder dealt with such simple subjects as water, air, pit-coal, smelting, lead ore, zinc, sulfur wells, slate, common salt, and saltpeter. Reading the essays is far from dull so that it is from a wealth of detail that the examples of Watson's "popular" discourse can be taken. Put yourself into the spirit of the latter half of the eighteenth century and assimilate something of what an educated person might learn about chemistry.

Unquestionably, Watson used what seemed to him the best authority for his time. There were many Greek and Roman writers whom he quoted as the ultimate source of knowledge, although however much he might have relied on Pliny and Homer, if the Bible offered information on the same subject, everything contradictory to the Holy Scriptures was rejected. When one remembers that his essays were almost all written after he assumed the chair of divinity, this was very logical. Again and again Watson quoted the *Philosophical Magazine*, until one is definitely impressed by the factual material of chemical nature which was obtainable there. Noted writers including Lemery, Scheele, Black, Bergman, Priestley, and Lavoisier were listed frequently. Look for the isolated facts of the period, accounts of the innumerable experiments, personally made, evidence of wide reading, and a rather definite tendency to emphasize the practical advantages of the science.

Any who are fascinated with the meaning and derivation of words may read these older chemical volumes with considerable pleasure. Besides the many early chemical terms, such as mephitic air, which the reader comes to accept as easily as the modern, there were delightful derivations by which Watson makes his meaning clear to his public. To illustrate, we learned that the two Greek words *αμα γαμειν*, which mean marriage of two metals, were the root of the word amalgam. Only secondary was the suggestion that the original was malagma, also Greek, and meaning a soft mass;

which is the information given in the modern dictionary. Cinnabar was presented as an African word meaning the blood of a dragon, instead of the Greek word for vermillion. Cannel coal was so called because the people used to burn it for a light to work by in winter instead of candles.

It was not unexpected to find that the bishop searched the Bible for proof of what he said. Since all his writings for the church and clergy gave evidence of his complete belief in the scriptures, it was very easy for him to accept literally whatever he found. To prove that chemistry started in the earliest days, he quoted the fact that "Tubal-Cain was an instructor of every artificer in copper and iron" [Gen. 4 : 22]. This circumstance proved beyond a doubt that one part of the metallurgic chemistry was well understood at that time. "The art of making wine was well known soon after the deluge from the intoxication of Noah" [Gen. 9: 21]. The Egyptians were skilled in the manufacturing of metals, in medical chemistry, and in the art of embalming, long before the time of Moses, since Joseph's cup was mentioned [Gen. 44 : 2] and the physicians were ordered to embalm the body of Jacob [Gen. 50 : 2]. Exodus related the accounts of the arts of dyeing leather red, linen purple, blue, and scarlet and distinguishing precious stones. All this must have been learned by the Children of Israel in Egypt. The learned bishop took care to point out that when the Golden Calf was strewn on the water by Moses, it had not necessarily dissolved, contrary to some authors, but was in such a fine state of subdivision that it remained suspended long enough for the Israelites to drink it. That air can keep a great quantity of water dissolved in it was indicated by the text, "God divided the waters which were under the firmament from the waters which were above the firmament" [Gen. 1 : 7]. No other evidence was required by Watson that the antiquity of metals antidated Pliny and Homer than that the earlier author, Moses, wrote, "Only the gold and silver, the brass, the iron, the tin and the lead, everything that may abide by fire, ye shall make it go through the fire and it shall be clean" [Numb. 31 : 22].

Watson ingeniously explained why the art of smelting, known before the flood, was lost. Even though all primitive peoples were Noah's descendants, it was not possible to assume that each man knew and practiced the art. Even if each group leaving the original settlement after the flood to populate the earth had included a metallurgist, that particular man might have died before they found ore and thus lost the art for that community. Knowledge of smelting was regained when it became necessary to clear the forests, which largely covered the earth, to prepare acreage for cultivation. The primitive method of burning the trees created such a great heat during the conflagration that some of the surface ores were naturally smelted, the effect observed and subsequent artificial efforts made to prepare the metal so obtained.

Biological chemistry was scarcely recognized, yet there were a number of instances where Watson pointed out that there was a relationship between chemical composition and disease. Medical people can find sensible remarks about the prevalence of goiter or wens among those people of the Alpine nations or voyagers to northern seas where they used snow water for drinking. Some philosophers thought that snow water was the cause of the wens, but Watson said it could not be, since there were no wens among the population of Greenland. There was none in Westmoreland which had high land and snow, and many in Derbyshire which was lower. Then to show convincingly that snow water was not the cause of what we call goiter, he pointed out that the disorder was known to be common in Sumatra. One reason for the belief that snow water was obnoxious came from its lack of air in contrast to the great abundance of air in running water.

To obtain healthful drinking water at sea, the distillation of sea water was described as "an imitation of Nature who gently warmed the oceans, carried moisture into the air to fall as rain and fresh water." A remarkable invention was displayed on H.M.S. Arrogant by the naval men whereby twenty-five gallons of water was prepared per hour, "perfectly well tasted and of less specific gravity than the best spring water in the neighborhood." Sir Richard Hawkins in the time of Queen Elizabeth had used some such scheme. The "modern" improvement consisted in dividing a huge kettle in half, cooking the pease or oatmeal for rations in one side and distilling water from the other. By this plan the same amount of fuel was considered to fulfil two services.

Although the reason was not clear, Watson recommended "fictitious cinnabar" for medicine, as impurity in the natural ore might be the cause of illness. In this connection Watson stated that mercury was found either as the mercury of Nature or mercury mineralized by sulfur. Close association with the mercury of nature was harmful. Evidence enough was the paralysis that developed in a man who stood over mercury vapor in the gilding trade for six months. Yet the high wages offered for such work were sufficiently tempting to attract men. When men absorbed the mercury in their systems it could be detected because copper tarnished in their hands and mouth. In like manner other elements could be absorbed in the body to excess. Absorption of sulfur tarnished silver in the pockets of the victim, and iron rusted in the pocket of the man who ate too much sulfuric acid in his food.

There was a reference to anatomy when Watson mentioned that the medullary substance was alike in man and animals. Because there were other analogies as well, Watson believed "that man should be thankful to his Creator for the preference to place us at the top of the scale, to make us, as it were, the first term of a series, descending indefinitely by imperceptible gradulations, and to particularize the class of animals to which we belong, by rendering it capable of forming a moral character." His conception of the orangoutang of Java, the Kaffir, Negro, American savage, Esquimau, and European in ascending series long preceded Darwin.

One food problem dealt with the use of sugar of lead to improve sour wine. The merchants found this material much cheaper than sugar and were inclined to use it, regardless of the effect on the consumer. Another method of increasing the quantity of wine for sale was to add vinegar, which had been treated with sugar of lead, to the wine cask. Deploring this practice, Watson was happy to announce its danger openly. A second food problem was considered quite serious. Watson knew that copper vessels were a peril in food production. On the continent there had been many sad cases recorded of fatalities from the use of copper dishes. Absolutely clean copper vessels might be all right and not be affected by vegetable acids. In any case, new vessels were more dangerous than old ones as the surface of the unused metal had pores with sharp points which in time were abraded and blunted to less activity. In 1754 in Sweden, the use of copper ware in the fleets was forbidden. This was quite a sacrifice, as one of the oldest copper mines in the world was in that country. Since copper was suggested as the cause of scurvy, the use of tinned copper was recommended; the British navy adopted it in 1757. Watson suggested that even the tin might be detrimental, particularly if arsenic was present in it. Fortunately, Cornish tin was said to be free of arsenic. Zinc, a comparatively new metal, was looked upon with favor for kitchen equipment and as a covering for copper, but Watson warned his readers that experiments should be carried on to determine whether zinc was harmless or not.

Copper which was a very permanent metal was considered by many to have possibilities for sheathing in ships. Lead had been tried to improve upon the old wooden sheaths, but the navy complained that the rudder irons and bolts which were under water wasted away to a great degree when a metal was used. This did not happen in unsheathed ships, or those with wooden sheaths. Watson suggested that the iron bolts might be preserved by covering them with tin or even silver as a protection.

The cosmetics were very briefly touched upon. Rouge was mentioned, and bismuth, or Spanish white. If ladies used the latter, however, they were strongly advised not to go into any of the many sulfur wells at Harrogate for a cure as they would find that they would be colored "quite black."

Two or three of the theories of contemporary importance stand out above the others. One was the existence of phlogiston. Watson never accepted the modern theory of combustion, as his final essay was completed too early to adopt it. The reader would have asked what is phlogiston? Watson replied, "You do not surely expect that chemistry will be able to present you with a handful of Phlogiston, separated from an inflammable body; you may just as reasonably demand a handful of magnetism, or electricity or electric body. There are powers of nature which cannot otherwise become objects of sense than by the effects they produce; and of this kind is phlogiston." The usual experiments were described to show the nature of phlogiston as a part of sulfur or a metal obtained from a calx by the addition of a substance which was in large part phlogiston, such as charcoal, tallow, or iron.

The part which air played in burning was considered in the usual way for this period. Either the air, which was known to decrease in volume, imparted something to the burning substance, or the air absorbed the phlogiston and became saturated with it. Any suggestion of the modern significance of Priestley's work in connection with phlogiston was wholly lacking. Dr. Priestley was described as "an inventive genius with indefatigable industry to whom the philosophic world was particularly indebted for his inquiries into the nature of fictitious airs."

The problem of transmutation is inevitable throughout chemical literature. Watson refuted the change from air to water, although water seemed to form from air on the outside of a pitcher on a cold day. The correct reason was advanced by the bishop that the air was saturated with water vapor and there was no more reason for adopting the older belief than thinking that you made saltpeter out of water when you put some of it in water and then evaporated the water. Along some coasts, the sea seemed to recede and leave land. Some philosophers considered that evidence of a possible transmutation of water into earth. Watson wisely asked if there were not spots where the sea water had invaded the land. If the geographers had been able to report that the proportion of land to sea had been the same in the last four thousand years, the biblical, and to Watson's mind, the authentic age of the earth, that would have answered the question. Van Helmont's famous experiment with his willow tree which had indicated to him that water was changed to vegetable and, therefore, to earthy material was discounted by Watson by the simple experiment of weighing leaves and pumpkins, freshly picked, after drying in air, and after incineration. A pumpkin weighing two hundred ounces was found to leave scarcely one ounce of solid which indicated that living vegetable matter was principally water and the original water of Van Helmont was never actually changed to earth. Watson knew that Lavoisier weighed a vessel before and after he had boiled a quantity of water in it. The weight of the sediment left after evaporating the water was approximately the same as the loss in weight of the vessel. "Surprising," said Watson, "that no one had thought of this before." Although he was not entirely convinced that only the loss of substance from the container contributed to the sediment from the water, he was ready to accept Lavoisier's conclusion. The Mosaic account of the creation in the second verse of Genesis began with "darkness upon the face of the deep." That might prove that earth came from water, but Watson states that the influence of light and air was neglected in the account. There were saline and oily particles in air whose composition was not known. To prove the possibility of the great variety of oil particles in air, Watson stated that in twenty pounds of earth one could grow four thousand different plants, each with a different oil.

There was no oil in the earth so that there must be additional factors in the adjacent air which had to be recognized in those experiments where water changed to earth.

Water introduced an interesting geographical observation that the earth must assuredly have a greater diameter from pole to pole than at the equator, due to the ice accumulating at the poles. Of course the increase of snow ought to dry the oceans, but, "The factor mitigating against this is the internal fire of the earth." If the snow was thin there was no effect, as the colder atmosphere had more influence on the snow, but if the snow was thick the internal heat melted the under side, since the colder atmosphere was such a distance away. Of course, the fires of summer did melt the surface ice to some extent.

Bishop Watson was exceedingly interested in the welfare of his country. The righteous indignation with which he undertook to sponsor religious or political reforms before the House of Commons or House of Lords had appeared previously in his desire to acquaint his countrymen with the possibilities of improved conditions in the industries by means of chemical applications. "It cannot be questioned that the arts of painting, brewing, distilling, tanning, making glass, enamels, porcelain, artificial stone, common salt, sal ammoniac, saltpetre, potash, sugar, and a great variety of others have received much improvement from chemical inquiry and are capable of receiving much more." Illustrations of his ideas combine originality with facts in a delightful manner. A potential inventor was lost in the clergyman.

Watson was certain that many combinations of metals had never been made. They would furnish mixtures more serviceable than any in use. The method of extracting the greatest possible quantity of metal from a given ore had not been ascertained with complete precision. Three new metals had been discovered recently, Pt, Ni, and Zn. Others might be discovered. Until Margraff had demonstrated the method, no metallic substance was extracted from calamine. This had necessitated the importation of zinc from India or Germany. The heavy "black jack," as the calamine was called, was used to mend roads or as ballast for ships sailing to foreign ports for a cargo. By comparing the weights of a cubic foot of several substances with that of black jack which contained zinc, Watson was of the opinion that the "cawk, kebble and mundicks," as he called them, possibly contained valuable mineral material which might be utilized if it could be extracted.

In the early times a mixture of ore and charcoal had been made to extract a metal. On this the fire was first directed by the prevailing wind. A hand bellows, the first great improvement, was bettered by the use of a water wheel to work the bellows. The "modern" workers had been able to rework heaps of iron left as worthless since the smelting depended on the "quantity and velocity" of the air. The replacement of charcoal by pit coal was also a "modern" device. Lead workings represented a great difficulty, because one-eighth to one-tenth of the slag from the furnace was still lead. The proprietors allowed their workers twenty shillings for every pig of lead worth thirty-eight shillings that they could get from the slag. The best the men could do was to make seven shillings a week. In spite of the modern improvements, Watson added that "there is a beneficial limit between the quantity of metal from ore to be obtained and the expense attending the operation which nothing but experience can ascertain." One instance cited where purification did not pay was the virtue of leaving a little copper in the silver. That not only made it harder for coinage but saved the labor of preparing the pure metal.

Two commodities were essential for war material. These were gunpowder and brass, both considered products of art rather than nature. The ingredients for the production of gunpowder were carefully prepared and stored. In 1417, Henry V gave directions for equipping his fleet with twenty pipes of willow coal powder. There was also at this time an edict against the exporting of gunpowder. Such was its value that even earlier, in 1386, two French vessels carrying gunpowder were captured and the powder considered worth more than all the remainder of the cargo. To obtain the niter requisite for gunpowder for the government, the earth impregnated with the dung of pigeons and urine of cattle belonged to the crown. In 1656 a law was passed that the saltpeter makers could not dig in houses or lands without the consent of the owner. The West India Company was bound by law to supply the government with five hundred tons of saltpeter £38/10 a ton or £45 in time of war. Also, in time of war with an enemy who had plenty of potash, but no saltpeter, the supplying of aqua fortis to him ought to be prohibited under as severe penalties as the supplying of saltpeter itself. Finally, in view of the importance of the material, "a plan might be contrived for the making of saltpetre in every county of the kingdom, by the very moderate labor of those whose idleness is at present a burden to themselves and a reproach to the police of the community, the paupers of the several parishes." Does this last sound altogether like an outmoded idea?

Brass production, so essential for the manufacture of cannon, was an industry advanced in the time of Queen Elizabeth. A century later the workers solicited the protection of parliament because the Swedish people had so lowered the price of brass wire that it could be imported at a lower sum than the British could make it. Under Edward VI it could not be exported legally because of its value. One interesting bit of advice quoted by Watson was that of a Roman maid to her mistress. The maid advised that the lady wash her hands after using her mirror of brass, as the odor of it might be detected. Counterfeit gold coins made in foreign countries might also be discovered by their odor in contrast to good British gold.

The commercial production of salt was another vital industry. Watson upheld the manufacture from sea water at Newcastle as economically sound because of

the cheapness of the fuel. It would not pay to do it where fuel was dear, even with concentrated brine. There was a very good description of the bay salt prepared in southern France and Italy by the evaporation of the sea water in shallow pits by the heat of the sun. The sea water was settled in one pit which was deepest to remove mud. Then it flowed into a second and then a third where "it concretes into crystals of salt." In a favorable season, the French could make enough of this salt in two weeks to supply their country for a year. The excess was exported. Here again art imitated nature, for Watson had heard of the great salt lakes mentioned by Pliny and seen by travelers to far countries. Go today to Provence and see this very method in use.

Although the making of bay salt was not practical in England on account of the climate, Watson offered a very ingenious method to obtain it if the need arose. He determined quantitatively how much water expressed in pounds would dry in an hour from a square yard of cloth. He knew also the amount of salt in sea water. By further calculations, he determined that one workman could keep one thousand yards of cloth moistened and evaporate twenty-four thousand pounds of water. If sea water had $^1/_{32}$ part of salt, the yield would be seven hundred fifty pounds. Another method of preparing excellent salt was that used by the Dutch who had to have it to pickle herring. They prepared their bay salt by evaporating the sea water with the gentlest fire and mixed the brine with very sour whey. The acid united itself with the uncombined fixed alkali and prevented its adherence to the common salt when it crystallized.

Although it would have been impossible in the eighteenth century to analyze materials completely, Watson was an ardent exponent of such analytical procedure as he could employ. He worked with his own hands, saying, "It is not enough to employ operators in this business; a man must blacken his own hands with the charcoal, he must sweat over the furnace and inhale many a noxious vapor before he can become a chemist." Many hours were spent in proving the most self-evident things to be true. Many experiments were but duplications of the work of others, but the spirit of the man was to see for himself before he imparted his information to the public. He also realized that his experiments had not been performed under exactly the same conditions. Surely here was the scientific spirit which expressed itself by the remark that "there is far greater trouble in making experiments than those who have not been accustomed to the business can readily conceive; many niceties are to be attended to, the least of which being omitted, the conclusion becomes doubtful."

Ready to show the practical relationships of his experiments, Watson pointed out that lime was often sold by weight. This made the absorption of air, as he called it, after heating, of very definite importance. The seller would be the gainer, if he let his lime stand. The farmer who bought the lime for his land should contrive to carry it off soon after it was burned as he might have to move for every ton of the original substance a half ton more. He would also have had to pay more for air which would be absorbed free of cost on the fields. Watson thought that this addition of lime would markedly increase the weight of the soil, but he admitted that he did not have enough skill in agricultural procedures to know whether this was an advantage or not.

A few observations relating to wood are worth quoting. Those who burned wood into charcoal ought to contrive means for saving all the oil which was separated from the wood during the operation. Perhaps some fixed alkali could be made of it. Watson determined the amount of water lost by oak and ash after they stood for some months. Strips of the same woods were soaked in water, weighed, and let stand to be reweighed. It was quite evident that it paid to make boards from the wood on the spot where the trees were felled to save carrying water. Paint, by deduction, not only preserved the wood from decay but kept a great deal of rain water out of carriage wheels, lessening the load the poor horses would otherwise have to draw. The fact that the wooden material, charred by the hot lava when Herculaneum was covered, had lasted through so many centuries led Watson to suggest that charring was an excellent method to preserve the wood used in mine construction.

There has been no effort to contradict or correct Watson's ideas in this account. The essays are filled with facts, right, wrong, or quaintly stated from the present point of view. That Watson was not merely a dilettante, but an authority, was shown by the references which Muspratt made to the bishop's chemical writings in the 1860 edition of his "Chemistry, Theoretical and Practical."

A quotation from Newton was hidden away in the essays. A certain Dr. Bently met Newton who asked him, "What philosophical pursuits are carrying on at Cambridge?" "None," replied Bently, "for when you go ahunting, Sir Isaac, you kill all the game. You have left us nothing to pursue." "Not so," said the philosopher, "You may start a variety of game in every bush, if you will but take the trouble to beat for it." Perhaps this is a fitting conclusion, for there is no doubt that Watson himself had the same spirit of investigation. What he could discover of interest among the common, every-day things of man's existence that could be interpreted with sense and reason appealed to him. Where Watson had to leave questions unanswered, he must have stimulated others to research. That was his worthy contribution to chemistry and science.

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PERSONNEL PLACEMENT VIEWS *on* CHEMICAL EDUCATION

FORREST A. ANDERSON

Wilkens-Anderson Company, Chicago, Illinois

WEBSTER defines education as "the systematic training of the moral and intellectual faculties." Any influences which will assist a student through his own efforts to develop mind, character, and body to the limit of his individual capacity for growth, and help him apply those powers, are worthy of consideration. In the light of this definition, we believe there are possibilities for improvement in our educational methods as applied to the training of chemists and chemical engineers. Some additions are suggested and extra-curricular activities advocated.

In talking with personnel placement scouts sent out by industry to interview prospective candidates for positions, the writer is informed that the strictly academic qualifications and training, and achievement of highest marks, is only part of the story in successful placement. A college education of this character in itself is not enough. In interviewing several thousand college graduates during the Depression, and placing hundreds in various industrial and teaching positions, the writer believes a more rigid selection should be followed by the colleges and universities in accepting students for chemistry and chemical engineering courses.

There surely must be the qualification of a really capable intellect, as well as of character and personality. The college must take upon itself the responsibility of ascertaining the presence or absence of these qualifications and of limiting for admission only those duly qualified. The percentage of people who go on for graduate work is relatively low. In the present changing picture of education, many feel that more time and attention should be given to those seeking the higher degrees, rather than to those who are taking the A.B. and B.S. degrees in chemical courses.

Personality development is receiving considerable attention in many universities at the present time. It is believed that through student counseling many young people may be aided. Many have come to believe this phase of education must receive attention, care and training in similar proportions to the development of the mind. Mental development comes through academic activities and is indicated fairly well by class marks. Physical growth comes through proper exercise and adequate physical hygiene and is summarized by periodic physical examinations. Moral growth and development is furthered by churches and similar organizations and is judged by the student's honesty, truthfulness, and other indices of moral characteristics. There does seem to be a need in the educational picture for this other phase of development called—for want of a better word—"personality growth." Staff members should at least see the importance of advising students concerning the relative importance of personality growth. Some will question the possibility of greatly influencing a student twenty years old. From those who have carefully kept a record of such educational endeavors, we learn that personalities may be improved in a large number of cases.

As a by-product of the recent Depression, several hundred poorly trained chemists and chemical engineers have walked the streets of the various metropolitan areas in search of positions in laboratories or plants. These comprise the people with one or two years of college chemistry, some being crippled in one way or another, and some hard of hearing. Many of the foreign-born had difficulty with speech and others even with foreign names were handicapped. In the temporary placement of such people in the chemical industries, the man and his lack of technic, the college that trained him, and the industry that tries to use his services, are all poorly served.

Very definitely the best possible ground-work for the particular science selected must be had. These ac-

tivities usually comprise the most of the background of training and take up the larger part of the student's day. Of course, almost any professor of chemistry will tell you he finds it impossible to inculcate enough of the bare essentials of chemistry and related subjects in a student. Certainly no chemical graduate knows too much chemistry. Practically all of them know too little else! Not a great deal of time is left for other all-important subjects.

Assuming for the moment the student is going to college for a period of four years or more to fit himself in the broadest and best possible manner for the business of life, it is only fair to assume that both interested parties should pattern their course of action to meet the needs of a changing business world. As the steel industry changes the shape, size, and character, of steel rails to allow for high-speed modern trains, so should the college be ever alert and seek to mold its products to better fit the modern needs. Many subjects considered as non-essentials by the student of chemistry play an important part in the picture of placement. Not a great deal of time can be devoted to certain of these subjects, but a fair amount of thought given to them during the college years will pay dividends after graduation.

For the energetic student who is seeking to broaden himself, extra curricular subjects are suggested, as follows.

Shorthand and Typing.—A working knowledge of shorthand and a reasonable degree of proficiency in typing have been found most valuable. This practical art not only enables the student to take notes quickly and easily in the classroom, but it is of the utmost importance in a business career. A typewritten letter of application for a position receives immediate attention. Science-trained women will find a ready market for their talents as chemical secretaries to business executives, where a knowledge of nomenclature, typing, and shorthand will materially assist them in securing profitable employment. Another field of endeavor for women is in science libraries, and here a reading and writing knowledge of scientific German and French is desirable.

Business English and Composition.—Judging from hundreds of letters of application for positions which were woefully lacking in some of the simplest fundamentals of business English and composition, we are led to suggest a more careful and diligent use of the time employed in the study of English. In the presentation of written and oral reports, many of the college graduates placed in positions have left much to be desired from the employer's viewpoint. Accurate and careful spelling and more attention to punctuation should be the goal of every serious-minded person seeking to make the most of his education.

Speech—Debating Societies—Professional Group Meetings.—A pleasant, well-modulated voice is a business asset of no mean worth. Clear, crisp, understandable English often gets the job on the first hearing. Judging from the mumbling which has come from science-trained people applying for positions in this metropolitan area, such courses in college are much neglected. The debating societies in the colleges give a most valuable training to those taking part in this form of activity. Participation in debates builds up a confidence of address and an understanding of the value of appearance, approach, etc., which can be carried through one's entire life.

Physical Training.—In a questionnaire sent out by the American Chemical Society in an endeavor to find "what the employer wants of the chemist," a large majority of replies placed great emphasis on the need for "Abundant Health." As the early period of training in one's life is the time for developing health habits, it is earnestly suggested that some time be devoted in college to this very necessary qualification.

Salesmanship—Business Psychology.—The average applicant for a science position has been found to be woefully lacking in contact ability, otherwise known as salesmanship. A strong course in psychology often supplies many valuable aids in selling one's services and is recommended.

The ability to keep a simple set of books has won many a man a job. This training gives more than just a cost sense and often helps one to see the other fellow's viewpoint, even that of the Laboratory Director who must make money for the group.

Many of the larger colleges and universities, recognizing the need for a closer study of modern student problems, have organized Personnel Service Departments for Personality Development, Student Counseling, Occupational Information, and Employment Placement. The value of such services to the student body cannot be over-estimated, and in educational institutions where the plan is receiving full coöperation of executive officers and staff, immeasurable benefits are being realized. These objectives are in keeping with the honest desire of the educational system of serving the youth of the nation with a plan geared to best fit the student for the business of life.

An isolated fact can be observed by all eyes; by those of the ordinary person as well as of the wise. But it is the true physicist alone who may see the bond which unites several facts among which the relationship is important, though obscure. The story of Newton's apple is probably not true, but it is symbolical; so let us think of it as true. Well, we must believe that many before Newton had seen apples fall, but they made no deduction. Facts are sterile until there are minds capable of choosing between them and discerning those which conceal something and recognizing that which is concealed; minds which under the bare fact see the soul of the fact.—HENRI POINCARÉ

The METAL CARBONYLS*

VII. INDUSTRIAL SIGNIFICANCE

WM. E. TROUT, JR.

Mary Baldwin College, Staunton, Virginia

VII. INDUSTRIAL SIGNIFICANCE

ASIDE from their interest to academic workers, the metal carbonyls early attracted the attention of investigators in industrial laboratories, who have secured a large number of patents covering proposed uses of these compounds. Although only a few of the suggested applications of the metal carbonyls have become important economically, interest in the compounds continues and we find a number of patents concerning them issued each year.

FIGURE 6
FROOD MINE, NEAR SUDBURY, ONTARIO
(*Courtesy of Chimie & Industrie*)

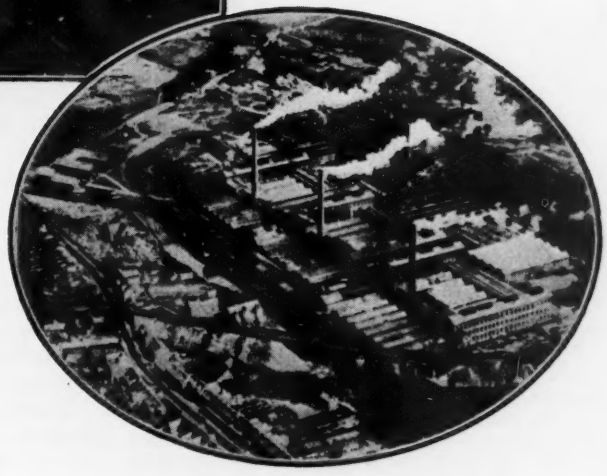


FIGURE 7
THE CLYDACH PLANT OF THE MOND NICKEL COMPANY, NEAR SWANSEA, SOUTH WALES
(*Courtesy of Chimie & Industrie*)

The Refining of Nickel (*92*).—Ludwig Mond's successful use of his discovery of nickel carbonyl in the purification of nickel has been referred to early in these articles. After preliminary trials in the laboratory, Mond built an experimental plant near Birmingham, England, and spent much time, energy, and money in developing a satisfactory process for separating nickel from Canadian matte. The plant was torn down and rebuilt several times before it successfully produced one and one-half tons of nickel weekly from Canadian matte containing forty per cent. nickel.

Thus having demonstrated the possibility of commercial production of nickel by the carbonyl method, Mond opened a refinery at Clydach, near Swansea, in South Wales, and began the extraction of nickel from matte which he now obtained from his own mines and smelted in Canada. In 1901, the Mond Nickel Com-

* This is the fourth of a series of articles concerning the metal carbonyls. The author reserves all rights to these articles.

pany, Ltd., was formed to take over the patents, mines, and plants. This company was operating successfully when it merged with the International Nickel Company. During the twenty-seven years up to 1928, the Clydach refinery produced more than 90,000 tons of nickel which was said to be of greater purity than that produced by any other process.

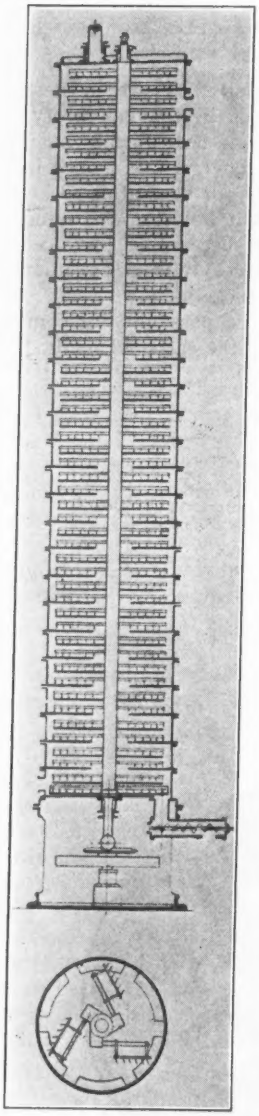


FIGURE 8
DIAGRAM OF A VOLATILIZER
(*Courtesy of the International Nickel Company*)

It is estimated that over ninety per cent. of the nickel produced in the world is obtained from mines of the International Nickel Company, the most valuable of which are within a mile or two of the Canadian town of Sudbury, Ontario. Of these mines perhaps the most important is the Frood mine, which extends over 3100 feet into an ore body which is estimated to contain at least 135,000,000 tons.

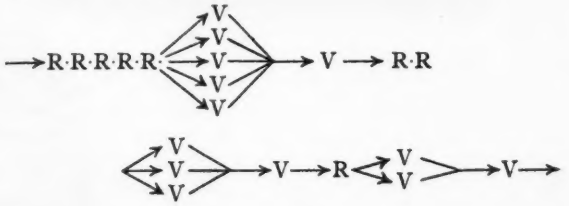
The ore, which contains 2.5 to 3 per cent. nickel, 1.5 to 2 per cent. copper, some iron, and small, but important, amounts of gold, silver, and the platinum metals, is first sorted over by the miners and sent to the surface. Here it is emptied on a belt conveyor and inspected. Some of the rock is eliminated. The ore is further broken up and sent to a smelter, such as that at Copper Cliff, a few miles away from the mine, where it is crushed to form particles resembling fine sand. Water is added and the material is subjected to concentration by flotation in a series of selective baths. The fine concentrate is dewatered, dried in a multiple deck roasting furnace, and then led into a blast furnace, or reverberatory furnace, where some of the iron sulfide is converted to the oxide. This oxide combines with the siliceous matter to form a slag which is drawn off in settling basins. The heavier nickel-copper sulfide mass is now placed in a Bessemer type converter such as the Pierce-Smith basic lined converter, where the blast of air removes some of the sulfur as sulfur dioxide and oxidizes the remaining iron to iron oxide. The iron oxide combines with an added siliceous (quartzite) flux to form a slag which can be drawn off, leaving a partially reduced copper-nickel sulfide matte containing about eighty per cent. nickel and copper, with rather more nickel than copper.

The remainder of the process of purification is carried out either by the electrolytic method in America, or by the Mond Process at Clydach.

At Clydach, the crushed matte is further crushed and ground until it passes through a sixty-mesh sieve. The powdered matte is then passed into calciners of straight-line double-deck, endless-chain type, where air converts the sulfides into oxides. The matte enters on the upper deck, is spread by means of ploughs on an endless chain, drops on the lower deck and is conveyed by ploughs back to the charging end of the calciner. During this treatment, the temperature, initially the same as that of the plant, gradually rises through a series of zones to a "finishing heat" of 780°.

The matte is then transported to the "Nickel Plants." Here it passes through a series of "reducers" and "volatilizers" which are arranged along one side of the plant. Opposite the volatilizers are the "decomposers" in which the nickel is formed.

On entering the plant, the matte passes through five gas-heated reducers in series, where about eighty-five per cent. of the oxides is reduced to metal. The reduced matte then passes through five volatilizers in parallel, where thirty-six per cent. of the nickel is removed as nickel carbonyl, which is led away into the decomposer on the other side of the plant. The remaining matte is combined and led through a single volatilizer which removes an additional eight per cent. of the nickel. Before it is discharged from the plant, the matte passes in turn through two more reducers in series, three volatilizers in parallel, a single volatilizer, a single reducer, two volatilizers in parallel, and finally a single volatilizer.



The matte remains in each reducer for about six hours and in each volatilizer for about eighteen hours. Before its discharge from the last volatilizer, the matte is in the plant a total of about six and one-half days.

The reduction is carried out at 330–350° by means of water-gas. The hydrogen effects about ninety-seven per cent. of the reduction and the carbon monoxide only about three per cent. The hydrogen content of the gas is therefore much reduced and the carbon monoxide content increased, making the gas issuing from the reducers suitable for use in the volatilizers as a source of carbon monoxide.

The volatilizers require no heating, for the reaction, $Ni + 4\,CO \rightarrow Ni(CO)_4$, is exothermic and the heat must be dissipated by radiation and conduction in order to maintain a temperature of about 50°. A diagram of a volatilizer is shown in Figure 8. The gases coming from the first volatilizers contain as high as four per cent. by volume of nickel carbonyl, and from the last volatilizer, about 0.4 per cent.

These gases from the volatilizers are passed into the decomposers on the opposite side of the plant, where they come into contact with moving nickel pellets at about 180°. Here the nickel carbonyl decomposes and deposits nickel on the pellets. The liberated carbon monoxide is returned with the gas stream through a manifold, to be used again in the volatilizers. Close control of temperature is necessary to avoid carbonization of the carbon monoxide, a reaction which becomes appreciable at about 200°. In each plant there are forty of these decomposers, thirty-five of which are in operation at a given time.

The nickel pellets are kept in motion in order to maintain their spherical shape and to keep them from cementing together with newly deposited nickel. They are carried to the top of the decomposer (Figure 9) and allowed to descend. As the pellets grow, some are pushed out of the decomposer at the top where they fall into a box and constitute the "make" of that decomposer. The decomposer is opened from time to time, and the pellets are removed and sorted. Those which are too small are returned for further accretion of nickel. The pellets ordinarily found on the market are about ten millimeters in diameter. The time required for the formation of spheres of this size varies from six to eight months.

In order to effect economy, the matte, which, after these operations, still contains thirty-six per cent. of the nickel originally present, is sent through the entire process twice more. Before each of the last two treatments in the plant, some iron is removed in smelting furnaces. After the third treatment, the matte is sent to a concentrating plant, where it is oxidized, and leached with sulfuric acid to form nickel sulfate. The remaining solid, containing precious metals, is shipped to the refinery at Acton, London, for the extraction of gold, silver, and the platinum metals. The importance of these metals in the by-products of the plant is made evident by an annual report of the International Nickel Company. Accompanying a yearly production of 90,000 short tons of nickel in all plants there were 120,000 short tons of copper, 40,000 ounces of gold, 1,500,000 ounces of silver, and 3000 ounces of the platinum metals.

For further economy, the sulfur dioxide formed in the calciners is converted into sulfuric acid by the contact process. This acid is used to leach out the copper, thus forming copper sulfate which is sold as powder and as large crystals. The acid is also used to leach the nickel from the matte discharged from the violatilizers, and these leachings are used to manufacture nickel sulfate and nickel ammonium sulfate. Furthermore, the heating and reacting gases needed are manufactured on the site of their use.

Iron Carbonyl as an Antiknock (*93*, *94*).—Antidetonants, better known as antiknocks, practically unknown before the World War, are now of capital importance. It is now common knowledge that most straight gasolines detonate under high compression rather easily. The modern desire to secure greater yields from gasoline and from motors has stimulated an active search for compounds which will reduce the tendency of the motor to detonate prematurely.

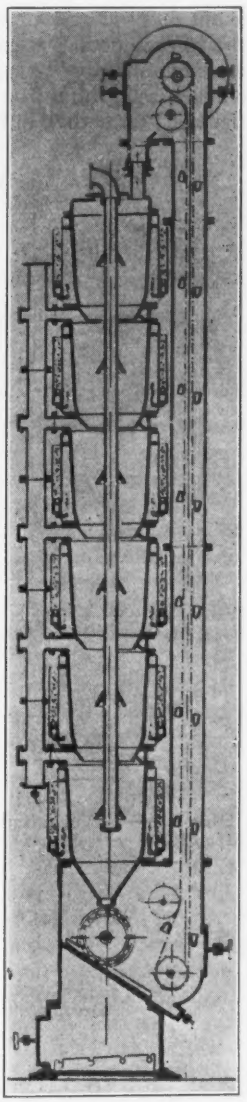


FIGURE 9
DIAGRAM OF A DECOMPOSER
(*Courtesy of the International Nickel Company*)

It was soon found that small percentages of impurities in the gasoline prevent premature detonation. Perhaps the best, certainly the most widely used, of these substances is the familiar lead tetraethyl, the "ethyl" of commerce.

Although lead tetraethyl is a very useful compound, unfortunately it is an insidious poison which alters the health long after it is absorbed, and may lead to mental illness or to death. Furthermore, lead tetraethyl is introduced into the organism not only by way of respiration, but also through the pores of the skin. These considerations, among others, have incited chemists to search for substitutes for lead tetraethyl.

In the refining of gasolines, especially when zinc chloride and ammonia were used for gum removal, it was discovered that some purified products had antiknock ratings as high as 96 octane. On standing, especially in the presence of light, the gasoline octane number was reduced to about 61. On investigation, the gasoline was found to contain small amounts of iron carbonyl which precipitated the enneacarbonyl rapidly on exposure to light. Less than 0.1 per cent. by volume of iron pentacarbonyl was found to raise the antiknock value by at least thirty-five integers. The

addition of three milliliters of iron pentacarbonyl to one gallon of gasoline raised the antiknock value from 58 to 96. Obviously, the use of iron pentacarbonyl as an antiknock deserved more investigation, and this study was pursued in a number of laboratories.

As an antiknock, iron pentacarbonyl appears to be about as good as lead tetraethyl. The efficiencies of the two compounds seem to be so nearly the same that some investigators favor the one, some the other. Not only is iron pentacarbonyl, in itself, much less toxic than lead tetraethyl, but its products in the exhaust are

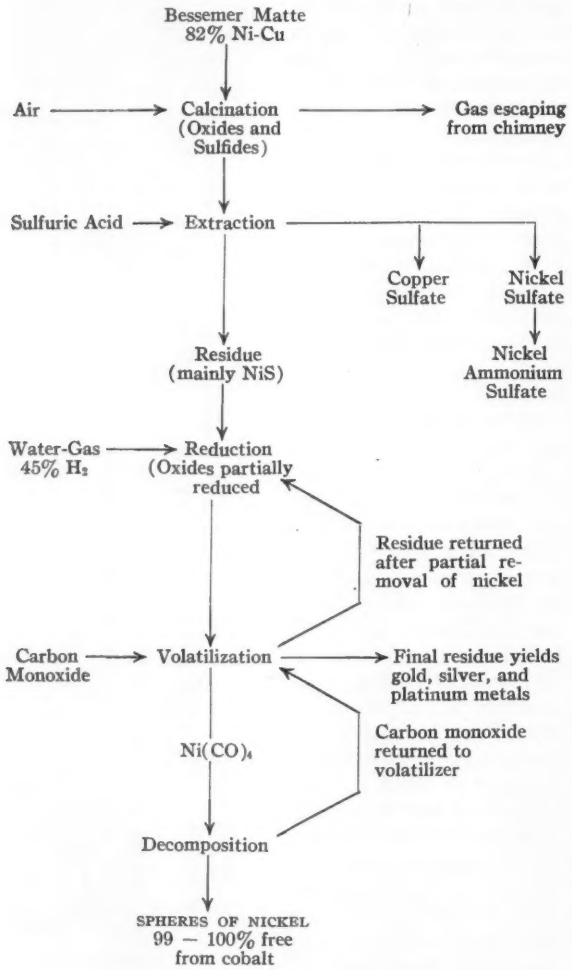


FIGURE 10.—DIAGRAM OF THE PROCESS FOR THE EXTRACTION OF NICKEL FROM CANADIAN MATTE BY THE MOND PROCESS

said to be much less toxic than those of the latter. The carbonyl is converted into ferric oxide, and carbon dioxide, along with carbon monoxide, some iron carbide, and some free iron.

Furthermore, iron pentacarbonyl is soluble in all proportions in gasoline, and possesses a vapor tension of 28.2 mm. of Hg at 18.4°; accordingly, it is conveniently carried into the carburetor in solution, easily volatilizes with the gasoline, and is readily carried into the explosion chamber.

One of the chief difficulties in the way of immediate substitution of the carbonyl for "ethyl" is the sensitivity of the iron pentacarbonyl to light, which, it will be recalled, decomposes it with the liberation of carbon monoxide and the formation of golden-yellow crystals of the enneacarbonyl. Widespread search ensued for negative catalysts—stabilizers—which would decrease or stop the photochemical decomposition of the carbonyl. A list of some of these compounds which have been reported in patents and elsewhere will indicate the scope of this activity. It must be borne in mind that the stability of the mixture in air, its physiological characteristics, and its cost of manufacture, all must be included in an evaluation of the usefulness of an inhibitor. Leahy (*93*) lists the following stabilizers which are cited in patents:

"Organic acids, esters, oxygen-containing organic compounds of high molecular weight, acetyl-acetone, 1,4-diparatoluenonanthroquinone, iron compound of acetyl-acetone, azo dyes such as aminobenzene combined with ethyl-beta-naphthylamine, typophorblack, adeps lanae, naphthenic acids, rubber, alpha-naphthalene-azo-alpha-naphthol, halogen-methanes, halogen-benzenes, toluidene, methyl aniline, ethyl aniline, normal methyl xylidine, ethylene chloride, chloroform, carbon tetrachloride, benzyl chloride, hexachlorbenzene, chloronaphthalene, ammonia halides and their organic derivatives such as methyl ammonium chloride, boric acid methyl or ethyl ester, tricresyl phosphate, zinc oleate, zinc isovalerate, chloral propionate, aluminum palmitate, calcium naphthenate, aromatic amines or their normal alkyl or normal aryl derivatives, secondary aliphatic amines containing up to three carbon atoms in the side chains, alcohols, dyes, aldehydes, ketones, stearic acid, valeraldehyde, butyraldehyde, alizarin, or lanolin."*

Leahy also reports the preparation of solutions of carbonyls which are apparently very insensitive to light. "Exposure to sunlight for twenty-three days had no visible effect on these solutions even in concentrated form."

Considerable difference of opinion is found among the investigators concerning the effects of the residue left in the motor. One author states clearly that iron carbonyl "does not leave any harmful deposits in the combustion chamber of the motor . . ." (*93*). On the other hand, a second investigator states that the use of iron pentacarbonyl as an antiknock "results in the depositing of iron oxide on spark plugs which finally causes shorting of the ignition. Also the iron oxide which collects in the lubricating oil produces undue wear of certain engine parts" (*95*).

Langeron (*94*), in 1927, reviewed the results of experiments at the Badische Anilin- und Sodafabrik and the I. G. Farbenindustrie A.-G., in which the problem of iron pentacarbonyl as an antiknock was investigated. First of all, methods of producing iron carbonyl in

* Acknowledgment is made to the *Refiner and Natural Gasoline Manufacturer* for kind permission to quote from Dr. Leahy's article.

large quantities were developed. It was also shown that 1,4-dipara-toluidoanthraquinone exerted a fairly satisfactory inhibiting effect on the photochemical decomposition of the carbonyl.

It was reported that the ferric oxide resulting from combustion of the carbonyl was largely expelled as smoke. Some of the oxide formed a coating on the walls of the explosion chamber, on top of the piston, and on the spark plugs, coloring them red after only several kilometers of travel. However, they report that the thin film, perhaps due to poor adhesion, does not appear to thicken, and, in time, is partly swept away. Bosch (*96*) showed that the spark plugs were not seriously interfered with.

We are all familiar with the efficiency of rouge as a polishing agent, and this property of the ferric oxide deposit, alone, would be sufficient to bar the use of iron carbonyl as an antiknock. However, it was shown by the Badische Anilin- und Sodafabrik that the ferric oxide formed in the combustion chamber did not polish the metal, apparently because of the small, almost colloidal, size of the particles.

Furthermore, the oxide which gets through into the lubricating oil appears not to affect the value of the oil. In fact, it seems to increase the lubricating powers, somewhat in the same way that graphite aids lubrication. In trials at the I. G. Farbenindustrie at Oppau, the coagulation of the oil, mentioned by other workers, was not detected.

The commercial high compression gasoline marketed by the B. A. S. F., known as "Motalin," contained 0.4 per cent. of "Motyl," a stock solution of equal parts of iron pentacarbonyl in petrol. The Motalin is almost colorless, whereas the Motyl is a light yellow liquid. Although iron pentacarbonyl has been tried in gasolines on the continent for some time, it has never become important as antiknock in this country.

The problem of the use of iron pentacarbonyl as an antiknock is yet to be completely threshed out.

Iron Carbonyls in Artificial Gases.—Since artificial gases contain carbon monoxide in varying proportions, from about five to thirty per cent., and, since during their manufacture and distribution the gases are in contact with iron, it is not surprising that iron carbonyls have a special significance in the artificial gas industry.

Carbon monoxide reacts with iron at nearly all temperatures used in gas manufacture, from room temperature to the highest operating temperatures. These reactions are indicated in the following table (*97*).

Iron carbonyls are formed only below 250°. At temperatures above 200° the carbonyls are largely dissociated into iron and carbon monoxide. The carbonyls, therefore, are not produced in the manufacture of the artificial gas but are formed only when the gas is cooled below 250° in contact with iron, for example, in purifier boxes containing iron oxide, in distributing pipes, in gas meters, and in iron piping at the consumer's home.

Evidence for the formation of iron carbonyls in artificial gases has been found by a number of workers. Perhaps the most spectacular report was made in 1916 by Mittasch (*98*), who found nearly 500 cc. of liquid iron pentacarbonyl in an iron tank containing illuminating gas. Other similar cases have been reported. Tanks of compressed commercial hydrogen containing a small amount of carbon monoxide as an impurity have been found to contain iron carbonyl (*99*). In a controlled experiment (*100*), thirty liters of

TABLE 3

REACTIONS OF IRON AND CARBON MONOXIDE

						Temperature Range
Fe	+	5CO	⟶	$Fe(CO)_5$		Room temperature to about 250°
Fe	+	CO	⟶	FeO	+ C	330–500°
FeO	+	CO	⟶	Fe	+ CO	200–800°
FeO	+	C	⟶	Fe	+ CO	Very high temperature
3Fe	+	C	⟶	Fe_3C		Very high temperature

gas containing thirty-nine per cent. CO under pressure of eight atmospheres furnished, in one-half hour of contact with the iron tank, 2.4 milligrams of iron per liter.

The iron carbonyl which is thus formed in stored gases is believed to be responsible for the red deposit sometimes found on gas burners. Experiments with water-gas (*100*) showed that where the gas impinged on the hot magnesium rods used for illumination, a deposit of Fe_2O_3 formed, lowering the efficiency of the light. Gunz (*101*) attributed the deposit of Fe_2O_3 on the cover glasses and porcelain reflectors of certain gas lamps to the decomposition of iron carbonyl. According to van Breukeleveen and Horst (*102*), deposits of iron oxide on gas mantles, lowering their efficiency, can be traced to iron carbonyl. Several suggestions have been made as to the best method of removing the iron pentacarbonyl from the gases (*102*). Passing the gas over hot copper at 300° has been used. Moistened potassium permanganate will remove the carbonyl. Addition of oxygen, chlorine, gaseous hydrogen chloride, or carbonyl chloride, followed by a porous body such as active carbon, has been suggested. Active carbon saturated with chromic acid serves well (*103*).

Coke oven gases and blast furnace gases at times burn with a white flame and deposit a soot containing iron. When the furnaces become well heated the blue flame of the gases is restored and iron is no longer present in the soot. This is explained by the low temperature formation of iron pentacarbonyl which at higher temperatures either does not form or is decomposed. The formation of iron pentacarbonyl in blast furnaces which are "working too cold" is thought to be responsible for the large deposits of Fe_2O_3 sometimes found in the downpipes leading from the furnace (*97*).

Iron Oxide from Iron Pentacarbonyl (*104*).—Very finely divided iron oxide may be obtained by heating iron pentacarbonyl below 100° under carefully controlled conditions. If the temperature goes above 100°, powdered iron is formed. Catalysts may be used to accelerate the formation of the oxide.

The fine oxide powder may be used for such divergent purposes as a coloring material for patent leathers, as a polishing powder, and as an agent for decarbonizing cast iron or steel by action on the molten metal. The carbon content of a steel may be lowered by treatment with the oxide, for example, from 0.5 to 0.015 per cent.

Carbonyl Iron.—As early as 1892 it was shown by Berthelot (*105*) that iron pentacarbonyl decomposed to form a mirror on a hot glass tube. It was not until 1924 that Diepschlag and Consbruch (*106*) reported that pure iron might be prepared in quantity by the thermal decomposition of iron pentacarbonyl.

No doubt many factors contributed to this long lapse between discovery and application. Certainly, one factor was the small yield of iron carbonyl obtained by early workers. When, in 1922, Mond and Wallis (*23*) used high pressure and high temperature to obtain iron pentacarbonyl from their apparatus in a steady stream, interest in the possibilities of iron from iron carbonyl could be seriously considered. Since then, by varying the conditions of formation and treatment, it has been found possible to prepare iron in such forms as scales, grains, more or less spongy masses, and powder, and this field of investigation has become one of major importance in the studies of the metal carbonyls.

Mittasch (*107*), working for the I. G. Farbenindustrie, A.-G., was the first to describe "carbonyl iron," an iron powder of unusual properties resulting from the thermal decomposition of iron pentacarbonyl. In his procedure, the carbonyl was heated by radiation to about 250° before it came in contact with the hot walls of the container.

The iron was in the form of a very fine powder, which consisted of remarkably spherical grains with diameters varying with the conditions between 1×10^{-3} and 1×10^{-4} millimeters. The powder is characterized by its great purity. The most exacting spectroscopic examination did not reveal traces of the sulfur, phosphorus, copper, manganese, nickel, cobalt, chromium, molybdenum, zinc, or silicon, which are ordinarily found in iron. The only impurities are carbon and oxygen, each present to the extent of about one or two per cent., and both apparently of much significance in the later treatment of the iron.

The preparation of pure iron from the powder has been of special interest to investigators, and this interest has been closely associated with the study of the unusual ease with which the powder may be sintered (*108*).

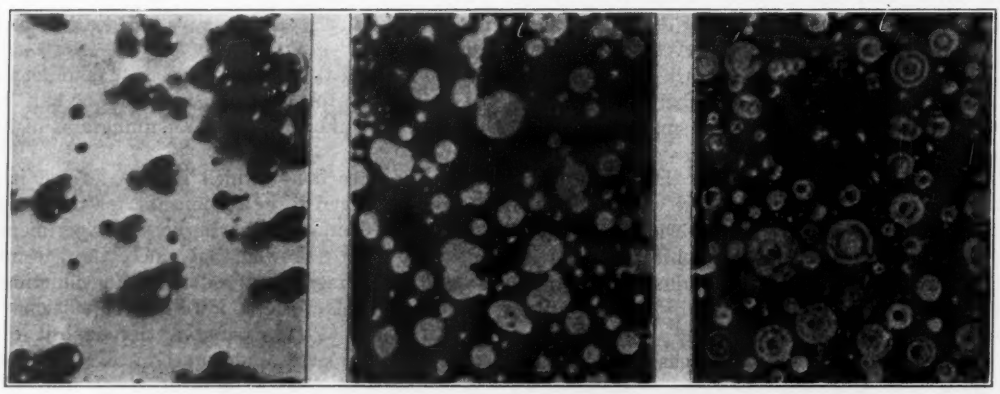


FIGURE 11
"CARBONYL IRON." (*a*) POWDER. (*b*) CROSS-SECTION. (*c*) ETCHED CROSS-SECTION
(*Courtesy of I. G. Farbenind. and Stahl und Eisen*)

When the powder is subjected to mechanical pressure in hydrogen or possibly in a vacuum, at a temperature below the melting point of the iron, it may be compressed into a solid without pores and with properties that are very useful. In this process, it is believed that the carbon and oxygen combine to form carbon monoxide and carbon dioxide. A typical ratio of recovered products is eighty-eight per cent. carbon monoxide to twelve per cent. carbon dioxide. With this gas are removed the surface impurities of carbon and oxygen leaving a pure, fresh iron surface, which sinters readily. The oxygen and carbon content of the impure iron powder appear to be just right for the success of this operation. The sintered iron is finally subjected to heat in a high vacuum, which removes the remaining gases.

Another factor favoring the ease of sintering of the powder is the regular size and spherical shape of the particles. A photomicrograph of these particles (Figure 11) clearly shows their unusual nature.

Of interest also is the suggestion that the tiny pellets are aggregates of extremely minute crystallites, the growth of which, when the temperature is raised only a

little, is unimpeded by the impurities generally found on the faces of crystals in metals as they are usually obtained. The enlarged crystals are much more stable and add much to the properties of the sintered iron.

The unusual properties of the sintered iron are indicated in Table 4. The final values of the oxygen and carbon contents are less than 0.01 per cent. Articles of sintered iron show high mechanical resistance, minimum contraction, and absence of pores. Investigators have been successful in forming discs of sintered iron which may be converted into plates, tubes, rods, wires, etc., of purity comparable to that of electrolytic iron. The iron thus prepared is extraordinarily soft, and possesses a ductility comparable to that of copper. Its resistance to corrosion is very high.

TABLE 4

PROPERTIES OF PURE CARBONYL IRON*

Mechanical Properties:	
Yield point	11 to 17 kg./mm.^{2}
Tensile strength	20 to 28 kg./mm.^{2}
Brinell hardness	56 to 80
Modulus of elasticity	2,070,000 kg./cm.^{2}
Notched bar toughness at 20° (test sample measured 10 × 10 × 100 mm., cross-section of fracture 10 × 5 mm., notch diameter 1.3 mm.)	16 to 20 mkg./cm.^{2}
Electrical conductivity	0.1×10^{-4}
Temperature coefficient of electrical resistance	0.65
Magnetic Properties:	
Coercive force	0.08 Gauss
Permeability, μ_0	3,000
Permeability, $\mu_{max.}$	20,000
Remanence	6,000
Saturation	22,000

* Cf. reference 108.

Mittasch (*107*) suggests that the carbonyl method may be used to recover pure iron from minerals difficult to treat otherwise; to prepare chemically pure iron for the laboratory and for pharmacy; and to manufacture magnet cores. He also suggests the carbonyl method for the construction of cables for long distance telegraph and telephone. These cables are usually constructed of powdered iron of toroidal shape subjected to high pressure with the grains insulated from each other by an organic or inorganic insulator. The permeability of such cables is said to be large and the loss by hysteresis small. These properties are thought to be chiefly due to the great purity of the powdered iron, and to the unusual nature of the sintered product.

The unusual electromagnetic properties of the carbonyl iron have been studied with some thoroughness, and it is found that in many respects this material compares well with the ferronickel alloys. Schlecht and his co-workers at the I. G. Farbenindustrie found that a technical sample of the purified iron had an initial permeability of about 3000, with a coercive force of only 0.08 Gauss.

Because of its purity and unusually regular grain shape, the powdered carbonyl iron may be used for the formation of alloys without danger of the formation of layers. The powders of the two metals to be alloyed are well mixed and sintered. The presence of the iron powder facilitates the reduction of the oxide coating on the metals, even of such a resistant oxide coating as that on zinc.

This method is especially useful in the formation of nickel-iron alloys from metal powders obtained by decomposition of the carbonyls of the two metals, either before mixing or simultaneously from a mixture of the vapors of the two metal carbonyls. Alloys prepared by sintering the two powders in hydrogen or in a vacuum showed electromagnetic properties which compared well with those of the alloys prepared by other methods. The similar preparation of alloys containing cobalt and molybdenum by decomposition of the appropriate carbonyls has been patented (*109*).

Catalysts from Carbonyls.—The possibility of preparing catalysts by the thermal decomposition of metal carbonyls has attracted a number of investigators. The

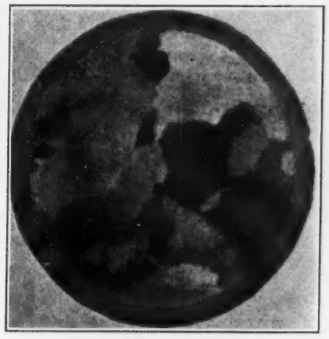


FIGURE 12

UNUSUALLY LARGE CRYSTALS WITHIN A PELLET OF CARBONYL IRON AFTER SINTERING AT 850° FOR 60 HOURS

(*Courtesy of I. G. Farbenind. and Stahl und Eisen*)

subject has been fully reviewed by Ellis (*110*). Credit is given to Shukoff (*111*) for the first use of this method in the preparation of a nickel hydrogenation catalyst. He passes carbon monoxide over finely divided nickel, forming nickel carbonyl which is swept directly into the oil to be hydrogenated. When the nickel carbonyl comes in contact with the heated oil, which is at 180°, it decomposes into carbon monoxide and finely divided nickel. As soon as the required small amount of catalyst is formed, the temperature of the mixture is raised to 220–240°, and the hydrogen is introduced.

One of the chief difficulties encountered in this process is the occasional trouble in removing the nickel by filtration. Ellis prepared catalysts by this method and states that the finely divided nickel may remain in suspension in the oil for days or weeks.

Miscellaneous Suggestions.—Many other interesting suggestions have been made concerning applications

of the metal carbonyls. Furthermore, a number of phenomena have been interpreted in terms of the formation or decomposition of these compounds. For example, Spurrier (*112*) attributes the brown spots on white pottery heated in carborundum crucibles to the oxide deposited from iron carbonyl. The iron carbonyl is thought to be formed from the iron present as an impurity in the carborundum.

The instability of iron pentacarbonyl in light has led to the suggestion that it be used in making blueprints (*113*). Such a blueprint may be made by soaking the paper in $Fe(CO)_5$, taking care to avoid exposure to light. After exposure to light and washing with water, a brown deposit of $Fe_2(CO)_9$ remains on the white background. The brown deposit is turned blue by washing with a slightly acid solution of potassium ferrocyanide, forming insoluble Prussian blue.

FIGURE 13
A FLAWLESS BLOCK OF FORGED CARBONYL IRON CONTAINING 1.36 PER CENT. OXYGEN
(*Courtesy of I. G. Farbenind. and Stahl und Eisen*)

Patents have been taken out for the preparation of hydrocarbons by heating the carbonyls in hydrogen. Another application in the field of organic chemistry is suggested by the reducing action of the metal carbonyls on certain previously mentioned organic compounds.

Attempts have been made to fashion articles by building up successive layers of nickel or of iron on molds by the decomposition of metal carbonyls. Nickel plating with nickel carbonyl has been investigated. The possibility of depositing nickel mirrors on the interior of Dewar flasks by the decomposition of nickel carbonyl has been studied, and although nickel was found to be a suitable metal for the purpose, the process has not yet become commercially available.

An indication of the range of suggested applications of the metal carbonyls is found in a patent taken out by Wittek (*114*) recommending that metal carbonyls, or their decomposition products, be used as plant stimulants. The patent suggests that the carbonyl may be added either to the soil or to the seeds of the plants, and that it may be used alone, or in fertilizers.

Since the carbonyls of nickel, iron, and perhaps cobalt may now be prepared conveniently in relatively large quantities, there is little doubt that further commercial possibilities of these compounds would be suggested, if it were not for the fact that the metal carbonyls are still rather expensive.

In concluding this review, we might point out that the history of the metal carbonyls is closely associated with the names of some of our most prominent chemists. Furthermore, the metal carbonyls present a highly attractive field to the industrial investigator. Finally, the peculiar compounds themselves are a challenge to the skill and imaginative genius of the experimenter and the interpreter.

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A BRIEF COURSE *in* COMMERCIAL CHEMISTRY *for* HIGH-SCHOOL STUDENTS

WILLIAM C. CURTIS

Cardozo High School, Washington, D. C.

Many students leave school before or at the end of their secondary training, and an increasing number of high-school graduates are returning to pursue postgraduate work. It would be advantageous to provide an opportunity for some of these students to obtain a knowledge of some of the practical phases of chemistry. Such training would also be valuable to students who plan to enter college. To this extent, it would be advisable to offer a second-year course in high-school chemistry which would emphasize the principles underlying certain vocations such as specialty manufacturing, household exterminating and disinfecting, elementary textile chemistry, and electrochemistry.

A course of this type would be utilitarian and vocational. It would help students to become intelligent consumer-buyers by acquainting them with the chemical principles, processes, and raw materials involved in the manufacture and distribution of commercial products. It would also provide a practical knowledge of chemistry which might enable some students to find suitable employment in later life. The subject matter of such a course could be adapted to the needs and abilities of the individual student, and should, as far as possible, comply with the demands of the local environment.

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A BRIEF course of elementary applied chemistry, with emphasis upon the chemical principles underlying certain occupations such as the manufacture of cosmetics and cleaning preparations, household exterminating and disinfecting, elementary textile, and electrochemistry, is described.

OBJECTIVES

I. To develop in students the ability to apply elementary chemical principles to the solution of everyday problems.

II. To aid students in their orientation by presenting some of the ramifications of chemistry in its relation to commercial occupations.

III. To aid students to pass normally from school into employment by providing them with a practical knowledge of chemistry.

REASONS FOR A HIGH-SCHOOL COURSE IN COMMERCIAL CHEMISTRY

Many students leave school before or at the end of their secondary training. Then, too, an increasing number of high-school graduates are returning to pursue postgraduate work. It is expedient, therefore, that the high-school curriculum should be expanded by the "introduction of utilitarian and vocational courses essential to the welfare of particular vocational groups." This expansion should be accompanied by adequate vocational and educational guidance. Chemistry as a high-school subject is well adapted to this development.

There are numerous opportunities of preparing high-school students for profitable and appropriate employment on a basis of a knowledge of the principles of applied chemistry within their comprehension. Some of these possibilities are specialty manufacturing, household exterminating and disinfecting, dry-cleaning operations, and electroplating. These vocations afford an excellent opportunity for developing a creative hobby.

Further, the consumer-buyer's economic problems are rapidly increasing in difficulty and importance. Consequently, students should be taught how to purchase commodities and services intelligently. The scope of high-school chemistry can be extended so as to

include a study of the processes through which commercial products pass in their manufacture and distribution and the relationship between their production cost and selling price. Such training would provide students with a rational basis for purchasing wisely.

METHOD OF CONDUCTING COURSE

A good method of conducting this course would be to devote the first two weeks to a study of certain fundamental chemical principles and laboratory operations. The prerequisite for this course should be one year of general chemistry. An alternative procedure, therefore, would be to go directly to the applications and "review the foundation principles spirally and incidentally." The organized review could be accomplished by means of recitations, readings, experiments, lectures, and individual reports.

The same procedure could be followed for the next four weeks covering the principles of business administration underlying the commercial occupations falling within the scope of the course and a systematic survey of the commercial products and processes with which an intelligent buyer-consumer should be familiar.

During the remainder of the course, the job contract plan could be very advantageously employed.[1,2] In this case, detailed outlines should be prepared on the subject matter to be used in the course. The students should be required to select the particular vocation for which they would like to be prepared or qualified. Subsequently, they should be given three or four separate assignments, in the form of jobs or units representing a series of related problems, to be mastered successively and successfully.

THE AMOUNT OF CLASS WORK

The average time required to complete this course should be two semesters. A minimum of seven class periods per week should be required, and the students should be allowed to proceed at their own rate of speed. They should have access to the laboratory equipment and reference material during these periods and leisure hours. Before beginning their experimental work, however, they should be required to show that they have at least a working knowledge of the experiment they are about to perform.

ASSIGNED READINGS

Since no textbooks suitable for a course of this type are yet available, the student will have to rely upon a number of books and periodicals. Such publications as those of the Consumer's Research, *The Drug and Cosmetic Industry, The National Cleaner and Dyer, The American Perfumer and Essential Oil Review, The American Druggist and Pharmaceutical Record, Food Industries*, etc., should be among the periodicals on hand. The required readings, along with an appropriate list of supplementary readings, should be included in the outline of the work furnished the student at the beginning.

OUTLINE OF SUBJECT MATTER

Local conditions should dictate the subject material to be used in a course of this type. The material selected should be adapted to the needs and abilities of the individual student. For the sake of brevity, the outline of subject matter which follows embraces only two phases of occupation included in commercial chemistry.

Introduction

The Basic Chemical Principles.
The Fundamental Laboratory Operations.

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BENNETT, HARRY, "Practical everyday chemistry," The Chemical Publishing Co., New York City, **1934,** 305 pp.
DULL, C. E., "Modern chemistry," Henry Holt & Co., Inc., New York City, **1931,** 776 pp.
GARARD, IDA D., "Applied chemistry," The Macmillan Co., New York City, **1924,** 496 pp.
RIEGEL, EMIL R., "Industrial chemistry," The Chemical Catalog Co., Inc., New York City, **1928,** 649 pp.

The Manufacture and Distribution of Commercial Products

The Processes and Raw Material.
The Relationship between Production Cost and Selling Price.
The Purchase of Commodities and Services.

Principles of Business Administration

A Survey of the Commercial Occupations Included in the Course.
Getting Started in the Various Vocations.

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Commercial Household Disinfecting and Exterminating Introduction

The Apparatus and Chemicals Needed.
The Chemical Principles Underlying the Profession.

Disinfectants and Disinfection

Disinfection Methods.
  Physical Methods.
  Chemical Methods.
Estimation of the Costs of Disinfection.

Fumigants and Fumigation

Fumigants.
  Preparation and Properties.
  Apparatus and Equipment for Application.
Fumigation Methods.
Estimation of the Costs of Fumigation.

Insecticides

Types of Insecticides.
The Preparation and Properties of Insecticides.

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The General Methods of Applying Insecticides.
Analysis of Commercial Insecticides.

Household Extermination

The Extermination and Control of Insect Pests and Their Relatives.
  The General Principles.
  The Specific Methods of Insect Control and Extermination.
The Extermination and Control of Rodents.
  The General Principles.
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Estimation of the Costs of Household Extermination.

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WILSON, ANDREW, "Insects and their control," Interstate Printing Corporation, Plainfield, N. J., **1931**, 383 pp.

Elementary Cosmetic Chemistry Introduction

The Purpose and Function of Modern Cosmetics.
Setting Up a Small Laboratory for the Preparation of Cosmetics.

The Chemical Principles Involved in the Preparation of Cosmetics

The Chemical and Physical Properties of the Materials Used.
The Chemical Principles of Compounding.
The Fundamental Laboratory Operations.
The Basic Formulas for the Preparation of Cosmetics.
The Chemical Analysis of Cosmetics.

The General Methods of Preparing Cosmetics

Solutions.
  True Solutions.
  Suspensions.
Colloidal Dispersions.
  Emulsions.
  Soaps.
  Gels and Jellies.
  Sticks.
Mechanical Mixtures.
  Powders.
  Cakes.
Emulsions and Mechanical Mixtures.
  Pastes.
Lixiviation Products.
  Extracts.
  Mucilages.

Specific Methods for Preparing Cosmetics

Preparations for the Care of the Skin.
Preparations for the Care of the Hair.
Preparations for the Care of the Mouth.
Miscellaneous Cosmetics.

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WHAT'S *in a* NAME?...

MARY ALICE EWING*

Sacred Heart Junior College, Wichita, Kansas

This paper purports to be a summation of the pronunciations and derivations of the names of the ninety-two chemical elements. Since the work involved is not experimental, but historical, its only claims to originality are its grouping of the elements, and its creation of an attractive setting and an informal atmosphere. It is the hope that both students and teachers will find the material included a compact and ready reference for classroom use.

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PERHAPS neither Juliet nor Shakespeare ever worked in a chemical laboratory; nevertheless, the dictum which Shakespeare puts into the mouth of Juliet is apropos even in chemical circles. Selecting a name for a newly discovered chemical element, however, has not been a matter of mere chance. Undoubtedly, much thought and study have been given to the christening of the new arrival in the chemical world. It is true, you and I, had we the opportunity, may have given names different from these, but, looking into the history of the technology assigned by others, I think we shall be willing to cede to our betters the honor of having chosen names most in keeping with the characteristics, the properties, the method of discovery, or whatever else history reveals to have been the reason for such assignment.

For the sake of convenience, let us arrange the ninety-

* Miss Ewing was a sophomore at Sacred Heart Junior College in Wichita, Kansas, during the academic year 1936-37. Her paper was written after she had completed ten hours of work in general chemistry under the direction of Sister Cecilia Agnes Bodine, C.S.J., instructor in chemistry.

two elements in ten groups which have been suggested by a historical search into the derivation of the names.

The first group consists of those elements which have been known for so long a time that the origin of the words themselves is obscure. To such a category belong antimony (ăn′-tĭ-mō-nĭ), bismuth (bĭz′-mŭth), iron (ī′-ŭrn), lead (lĕd), sulfur (sŭl′-fŭr), tin (tĭn), and zinc (zĭnk). We read in "The Discovery of the Elements," by Mary Elvira Weeks, that Berthelot believed metallic antimony to have been used by the ancient Chaldeans, and that he based this belief on his analysis of a vase brought to the Louvre from the ruins of Tello. The same writer is our authority for the statement that metallic lead was used by the Babylonians, and that both bismuth and tin were also well known to the ancients. They failed to distinguish, however, either of these elements from lead. Tin was called *plumbum candidum*, or the white variety of lead, while lead was *plumbum nigrum*. Although the etymology of the word bismuth is dubious, the name can be traced to the German, *Wismuth*, of the sixteenth century. Our knowledge of the antiquity of iron is brought out by Miss Weeks who refers to Job's allusion to the "iron pen." In ancient times sulfur was known as brimstone and the Bible frequently refers to it as such. The word zinc was used by the Greeks in the sixteenth century, but it was not applied to the metal now called by that name until the end of the seventeenth century.

Early man was observant, not only of his material surroundings, but also—and in a marked degree—of his celestial environment. Out of his considerations of the heavens grew the science of astronomy, and to this science, chemistry owes some of her most fantastic names. Helium (hē′-lĭ-ŭm) is taken from the Greek word, *helios*, which means sun. During the eclipse of the sun in 1868, a gas hitherto unknown was found to be present in the sun's atmosphere. The gas was called helium. The sun is not the only heavenly body which has a name-sake among the elements. For, following closely upon the discovery of early nineteenth century asteroids, came the detection of two new chemical elements. And while the world at large still talked of Pallas and Ceres, chemists talked of palladium (pă-lā′-dĭ-um) and cerium (sē′-rĭ-um). Uranus, one of the largest planets, has lent its name to the heaviest of the known chemical elements, uranium (û-rā′-nĭ-um). In our solar system, Uranus is the planet farthest removed from the sun. Is there, perhaps, also a significance in the fact that of all the known elements, uranium is the one which has its electrons farthest removed from the nucleus of its atom? Mercury (mûr′-kû-rĭ) was named for the planet, which in turn was named for the winged messenger of the gods. Hence its second name "quick-silver" is also quite suitable. Because another element was found in an ore, Klaproth called it tellurium (tĕ-lû′-rĭ-ŭm) from *tellus*, the earth. Some years later, a semimetallic element from the same source proved to be a new element instead of tellurium. Berzelius gave it the name selenium (sĕ-lē′-nĭ-um) which is derived from the word *selene*, the moon. The Greek goddess of the moon was Selene, from whence *selene* is derived. Its white, moon-like luster suggested its scientific name. Since it so highly resembles tellurium that it was for some years a mistaken identity, it seems appropriate also that the satellite of tellurium should be named for the satellite of the earth. It is curious, too, to note in how many ways the analogy holds. Recent investigations show that the selenium content of plants is responsible for a condition among animals known as "blind staggers," similar to the condition thought by early man to be due to Luna—another name for the goddess of the moon—who by her silver arrows struck madness into the brains of men. Again, the photoelectric cell owes its light-sensitivity to the element selenium which conducts an electric current only when a beam of light falls upon it. The moon also reveals her presence only by a beam of light from the sun.

As can be seen from the naming of mercury and of selenium, astronomy and mythology are closely associated. And quite as interesting are other names borrowed from the science of the myths. Because a certain metal seemed to take delight in hiding when chemists attempted to isolate it, Ekeberg gave it the name of tantalum (tăn′-tà-lŭm). Thus the story of Tantalus, whom the gods tortured, lives today in the story of these scientists' tantalizing task. Vanadium (và-nā′-dĭ-um) was named for Vanadis, the Scandinavian goddess of beauty. And although Klaproth named titanium (tī-tā′-nĭ-um) for Titan, he admits that titanium bears no relationship to uranium as is the case in mythology where we read that Titan is the son of Uranus. In 1828 Berzelius named a new element, thorium (thō′-rĭ-um), for the Scandinavian god of thunder, probably only because he liked the name. Seventy years later when Mme. Curie proved that the element emits light rays, the fitness of the name was realized.

Bordering the mythological and geographical is the land of Thule, from whence is taken the name thulium (thū′-lĭ-um). But leaving the imaginary Northland and arriving on *terra firma*, we see written in the table of the elements the loyalty of scientists to home and country. Columbium (kŏ-lŭm′-bĭ-um) is named for the United States. Niobium (nī-ō′-bĭ-um) has also been applied to the same element; however, the former name is steadily replacing the latter. Virginium (vĕr-jĭn′-ĭ-um), alabamine (ăl-a-băm′-ĭn), and illinium (ĭl-ĭn′-ĭ-um) are so-called in honor of the states Virginia, Alabama, and Illinois, respectively; or, according to some, in honor of the state universities in which these discoveries were made. As Columbia honors columbium, so Europe honors europium (û-rō′-pĭ-um). Polonium (pō-lō′-nĭ-um) is named for Poland, the native land of its discoverer, Mme. Curie. Germanium (jĕr-mā′-nĭ-um) was named for Germany, fatherland of Winkler who discovered it. When Noddack, Tacke, and Berg applied the names masurium (mä-zōō′-rĭ-um) and rhenium (rĕn′-ĭ-um) to their newly discovered elements they were mindful of former possessions lost to Germany during the World War.

Russia is represented in the list of chemical elements by ruthenium (rōō′-thē′-nĭ-ŭm) so called because it was found in the Ural mountains where the Ruthenian people live. Gallium (găl′-ĭ-um) is derived from *Gallia*, the Latin name for France. It was named by Lecoq di Boisbaudran, its French discoverer. Lutecium (lû-tē′-shĭ-um) comes from the word Lutetia, which was formerly applied to the modern city of Paris. The quartet of elements found near Ytterby, Sweden, quite loyally bear the names, erbium (ûr-bĭ-um), terbium (tûr′-bĭ-um), ytterbium (ĭ-tûr′-bĭ-um), and yttrium (ĭt′-rĭ-um). Hafnium (hăf′-nĭ-um) comes from the ancient name for the city which we call Copenhagen. Holmium (hōl′-mĭ-um) is from the Latin *Holmia*, for Stockholm which was the home of Cleve. Scandium (skăn′-dĭ-um) is the "metallicized" form of Scandinavia. From Strontian, Scotland, proceeds the name as well as the discovery of strŏntium (strŏn′-shĭ-um). Magnesium (măg-nē′-zhĭ-um) is taken from Magnesia, the name of a district in Thessaly. Davy proposed calling the element magnium to avoid possible confusion with the word manganese; however, the suggestion was not heeded, and we call the metal magnesium. Even Cyprus is remembered in the anglicized copper (kŏp′-ēr), for *cuprum*, which was derived from Cyprus, near which were located rich copper mines.

A prominent part in the naming of elements has been played by color. The Greek word, *chroma*, meaning color was applied to chromium (krō′-mĭ-um) because of the various colors which it lends to its compounds. Chromium has no characteristic color. Iridium (ī-rĭd′-ĭ-um) comes from the Latin, *iris*, meaning the rainbow. Iridium gives the property of iridescence to the solutions of some of its compounds. Certain characteristic color lines in the spectrum of various elements have been the means of detecting the presence of these elements. Caesium (sē′-zĭ-um) comes from the Latin word *caesius* meaning sky-blue. Caesium, when viewed spectroscopically, gives two characteristic bright blue lines. Indium (ĭn′-dĭ-um) was identified by the indigo lines which are produced by the spectroscope. Thallium (thăl′-ĭ-um) produces green spectroscopic lines; hence scientists made use of the Greek word, *thallos*, meaning budding twig. Rubidium (rōō-bĭd′-ĭ-um) which was taken from the Latin *rubidus*, red, manifests a dark red color-line in the spectrum. Departing from spectroscopy, rhodium (rō′-dĭ-um) was named from the Greek word *rhodon* which means rose. The name was applied to this particular element because several of its salts are rose-colored. Praseodymium (prā′-sē-ō-dĭm′-ĭ-um) one of the twins from didymium (dĭ-dĭm′-ĭ-um) which was once thought to be an element, received the prefix taken from the Greek *praseos* which means leek-green, because of its many green salts. Didymium itself means twin and was so-called because of its close association with lanthanum. The familiar greenish yellow color of chlorine gas is responsible for the name chlorine (klō′-rĭn). The Greek *chloros* means pale, greenish yellow. Violet vapors of sublimed iodine (ī′-ō-dĭn) suggested the Greek *iodes*, meaning violet.

Then, too, a number of chemists gave the elements which they isolated names which reveal characteristic properties other than color. Some of these properties are physical; others are chemical. For instance, osmium (ŏs′-mĭ-um) received its name from the Greek word, *osme*, which means odor, because of the chlorine-like odor of osmium tetroxide. Bromine (brō′-mĭn) from the Greek *bromos*, meaning bad smell, has the bad name as well. Argon (är′-gŏn) comes from the Greek *argos*, meaning lazy. Argon isn't exactly to blame. It belongs to an inactive family. Oxygen (ŏk′-sĭ-jĕn) was once thought to be an essential part of all acids and was mis-named "the acid-former." Nitrogen (nī′-trō-jĕn) means niter-former or "material of nitre." Hydrogen (hī′-drō-jĕn) is called water-former because its oxidation results in the formation of water. Protoactinium (prō′-tō-ăk-tĭn′-ĭ-um), meaning parent of actinium, received its name from the fact that it emits actinium atoms by means of its property of radioactivity. Actinium (ăk-tĭn′-ĭ-um) itself is derived from the Greek word for ray because it, too, possesses this characteristic of atomic disintegration. Radium (rā′-dĭ-um) and radon (rā′-dŏn), also radioactive elements, were named from the Latin word *radius*, meaning ray. Although radon is a disintegration product of radium, it, too, is radioactive. Phosphorus (fŏs′-fŏr-us) comes from the Greek word meaning light bearer, because of its peculiar quality of glowing in the dark. Gold (gōld), according to some, is an outgrowth of a word meaning yellow. Most metals are silver-white in color. Gold is an exception to this rule. Beery, however, in her book "Stuff" tells us that the name for gold in all languages means "to glitter." Arsenic (är′-sē-nĭk) is so-called from the Greek, *arsenekon*, meaning yellow orpiment. The masculine gender is used because of its strength. St. Albertus Magnus discovered that it was a semimetallic element and called it *arsenicum rex*. Manganese (măn′-ga-nēs′) is derived from the Latin *magnes*—magnet. It was originally confused with magnetic oxide of iron. Etymologically, the word silver (sĭl′-vĕr) from the Anglo Saxon *seolfor* probably refers to the shining appearance or brightness of the metal. Spanish miners called a metal, which they sometimes found associated with gold or silver ores, *platina* because of its resemblance to *plata* the Spanish name for silver. We call the metal platinum (plăt′-ĭ-num).

The names of many chemical elements refer to the actions involved in the discovery rather than to any property of the element itself. Such is lanthanum (lăn′-tha-num) which in Greek means to conceal. It was so named because of the difficulty of separating it from cerium and other rare elements with which it is usually associated. Dysprosium (dĭs-prō′-shĭ-um), one of the rare earths, has a name which comes from the Greek word, meaning hard to speak with. Dysprosium was hard to isolate. Cobalt (kō′-bôlt) comes from a word meaning goblin. Metallurgists at one time were puzzled by the fact that they were unable to extract a metal from a certain mineral which, from its

weight, should have contained one. They finally isolated the metal whereupon they named the mysterious substance cobalt from *Kobold* which means goblin. Nickel (nĭk′-'l) was originally called *kupfernickel*. The ore from which it was taken seemed to contain copper but yielded none. Hence it was known as "Old Nick's copper." Neodymium (nē-ō-dĭm′-ĭ-um), the new twin, was the result of the discovery that didymium was a mixture of two elements. To one was given the name of praseodymium as related above and to the other the name neodymium.

Some of the elements were named from the source of their discovery. Fluorine (flōō′-or-ĭn) comes from the Latin *fluere*, to flow, because of its occurrence in fluorite which is used as a flux. The Greek word *barys*, heavy, was applied to barium (bā′-rĭ-um) because of its presence in barytis or heavy spar. Tungsten (tŭng′-sten) means heavy stone. The element was isolated from wolfram, a tungstate of iron and magnesium. Silicon (sĭl′-ĭ-kŏn) is related to the Latin word, *silex*, flint, in which it is found. Cadmium (kăd′-mĭ-um) was discovered in Cadmean earth and is frequently found associated with zinc. Cadmium means calamine which is a zinc silicate. Zirconium (zĕr-kō′-nĭ-um) was found in the silicate called zircon. *Calx, calcis*, meaning lime, is the source of the word calcium (kăl′-sĭ-um), so-called by the chemist Davy from its occurrence in chalk. In a like manner was lithium (lĭth′-ĭ-um) named. The Greek word *lithos*, meaning stone, was resorted to because of the fact that this element was discovered in a mineral. Beryllium (bĕ-rĭl′-ĭ-um) was discovered as a constituent of the mineral beryl. It is also sometimes known as glucinum (glōō-sĭ′-num) from the Greek *glykys* which means sweet. Some of the salts of this metal have a sweet taste. Samarium (sa-mā′-rĭ-um) is found in the mineral samarskite. When Gay-Lussac and Thenard isolated an element from boric acid they called it boron (bō′-rŏn). Sodium (sō′-dĭ-um) was isolated from soda and potassium (pō-tăs′-ĭ-um) from potash, the French of which is expressed by *potasse*.

As in most groups there are the miscellaneous, so are there among the names of the chemical elements. Aluminium (ăl-ū-mĭn′-ĭ-um), commercially known as aluminum, has had a difficult time in finding a name that it could hold. It was first called *alumine* from the French word for alum. Davy who proposed *alumine* changed it to aluminum, then to aluminium to conform to the customary ending of metallic nomenclature. Carbon (kär′-bon) comes from the Latin word for charcoal. Molybdenum (mō-lĭb′-dē-num) comes from the Latin *molybdaena* meaning galena which is derived from Greek meaning lead. Neon (nē′-ŏn), belonging to a chemically inactive group, was novel; hence the term *neon*, meaning new, was applied. Similarly, has the rare atmospheric gas been called krypton (krĭp′-tŏn). The Greek word from which it was taken, *kryptos*, means hidden. It is not hard to understand why this word was chosen when we realize that krypton occurs in the atmosphere in the very small proportion of one volume in twenty million volumes of air. Xenon (zĕn′-ŏn) means strange. It is found in the proportion of one volume to one hundred seventy million volumes of air.

It is customary for one who detects or isolates an element to name his discovery. The names applied to the ninety-two elements certainly prove that truly outstanding scientists capable of these great accomplishments are on the whole self-sacrificing men who have devoted their labors to scientific progress rather than to vain pomp and glory; for, though it be their privilege, they have not applied their own names to the newly found element. Gadolinium (găd-ō-lĭn′-ĭ-um) has the distinction of being the only element which bears the name of its discoverer; and that name was bestowed upon it by Marignac, friend of the Finnish chemist Gadolin, after the latter's death.

As indicated in the case of aluminium, it has been suggested that all metals have a terminology ending in the suffix -ium and that all non-metals use the suffix -ine. Scientists who have named elements in late years have adhered to this system. Thus we see that virginium is supposedly metallic while alabamine is supposedly non-metallic.

A study of the nomenclature of the elements has proved to be most revealing. Undoubtedly, the lovely Juliet and the sagacious Shakespeare will continue to assert,

> ". . That which we call a rose
> By any other name would smell as sweet,"

but study the etymology of the names of the elements if you really want to know "What's in a name?"...

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A LABORATORY EXERCISE *in* GENERAL CHEMISTRY

W. V. BURG

University of Toledo, Toledo, Ohio

Elementary laboratory courses in general chemistry can be greatly enriched by the including of coöperative exercises, provided the latter are organized in such a way as to reveal their full educational values.

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THE laboratory method most widely adopted in elementary general chemistry is to have all the students of the same class do the same experiment at the same time. The advantages and disadvantages of this method are too well known to require any further discussion. Attention may, however, be called to the fact that—according to the author's experience—such a laboratory course can be greatly enriched by including a few exercises which are based upon an entirely different principle.

In these exercises, too, the whole class is to work for the same objective but the different students are to attack it from different angles. Two major advantages of this method may be pointed out: it permits the distribution of the assignments according to the abilities of the individual students, and it stimulates the interest and responsibility of the students, since their work is a necessary part of the common effort of the class. Even the fact that in most cases, on account of the size of the section, at least two students must be engaged in the same experiment does not diminish the importance of each single performance, for only close agreement of the results of these experiments will render them useful for the work of the class. It may, furthermore, be mentioned that with laboratory sections of reasonable size and with adequate preparation on the part of the instructor the supervision of such an exercise can be done without difficulty, provided the objective has been selected with special care.*

Exercises of the kind referred to in this article generally consist of five main divisions, the nature of which will be briefly discussed. (1) The instructor introduces the exercise and gives the directions necessary for a satisfactory performance. (2) The students carry out the experiments which vary considerably with respect to the difficulties. The results are checked by the instructor. (3) The students communicate their results to the class by means of reports and demonstrations. (4) From the various results a problem is abstracted which is attacked by the whole class under the guidance of the instructor. It is essential that the students are prevailed upon to seek the solution with as little help as possible. (5) The instructor concludes the exercise by clarifying the remaining questions, giving additional information, and extending the study beyond the original limits.

The following description shows how a class of average students, who had had no previous training in chemistry, carried out an exercise of the kind mentioned above. The exercise was given at a time when the students had become familiar with a number of non-metallic elements and their compounds. In the periods just preceding the exercise the fundamental properties and reactions of the acids, bases, and salts had been studied. The object of the exercise was formulated as follows: to examine two substances, one being a white powder, the other one consisting of colorless crystals, and to compare their properties. (The substances were soda ash and sal soda).

Before the assignments were passed out to the students, the nature and purpose of the exercise were briefly discussed. Special attention was called to the fact that each student was responsible for the successful solution of the problem. It was, furthermore, mentioned that the students who had done less satisfactory work before would receive easier assignments. Those students, however, could show by today's performance that they were qualified to do a more difficult part the next time. Finally, some directions were given out as to the use of the written instructions, the practical procedure, the recording of the results, and so forth. Then the assignments were distributed and the students began to work.

One of the students had to counterpoise some of the crystals on a sensitive balance and to watch for some time whether a change would occur. Furthermore, he had to study the dissolving of the crystals in water. He finally had to prepare a dilute solution and to test it for feel, taste, and litmus reaction. A number of interesting observations were made: the change the crystals underwent on exposure to air; the absorption of heat on dissolving in water; and the alkaline character of the aqueous solution.

Another student had to examine the white powder in the same manner. He had to proceed with par-

* The reader might object that several of the well-known laboratory manuals contain exercises which engage the different students of a class in different experiments. Exercises of this kind are, for instance, the study of the action of a metal upon different acids, or the study of the solubility of a substance in a solvent at different temperatures. These exercises, however, are fundamentally different from those referred to in this article as will be seen from the example given.

ticular care in order to observe the liberation of heat when the powder was dissolved in water.

More difficult than those two assignments was the one a third student had received. He had to determine whether the white powder would undergo a change when subjected to heat (below 300°C.). At first a qualitative test was performed. No change seemed to take place. A quantitative determination then followed which proved that the powder did not change its weight when heated.

Another student carried out the same experiment with the crystals. The qualitative test showed that water was given off by the substance. It also revealed that the quantitative determination had to be done with particular care in order to avoid any loss due to spattering. The final result—confirmed by a second determination—indicated the percentage of water driven out of the crystals.

While the students had obtained rather detailed instructions for the experiments mentioned so far, more independence was assumed in another assignment. The student had to prepare an aqueous solution of the white powder and to treat it with dilute hydrochloric acid until no further reaction could be observed. Then he had to isolate the dissolved substance and to investigate its nature. Though the first part of the assignment was soon performed, the student encountered some difficulty in his further operations. From previous experiments he had been used to evaporate the solution until the first solid particles appeared and to complete the process by cooling. He found that in this case cooling did not have the desired effect, and he was forced to continue evaporation. The crystals finally obtained were carefully examined by means of a magnifying glass. The student observed their cubic shape and concluded that they might consist of common salt. He verified this conclusion by tasting the crystals and by applying the flame test. Since only the chlorine had been added by means of the acid, the sodium must have been present in the original substance.

Analytical features were also found in another assignment which required a still higher degree of independent thinking. The student had to treat some of the white powder with dilute hydrochloric acid and to investigate the phenomenon he would observe. Not very much was said in the instructions, since the student was to find his way with as little help as possible. The first steps were easy enough. When treated with hydrochloric acid, the substance started to effervesce. A colorless and odorless gas was evolved. Since the gas had neither color nor odor, it could not be chlorine. The student now tested for oxygen. The result was negative. Since the gas did not burn, it could not be hydrogen, either. Could it be nitrogen? The student considered this possible since the gas was colorless and odorless, did not burn, and did not support combustion. As he knew on the other hand that nitrogen was slightly lighter than air, the relative density of the gas was tested. The student prepared a little gas generator, connected it with a pneumatic trough and collected the gas in a cylinder over water. The closed cylinder was placed on the table in an upright position and the glass plate removed. After some time the contents of the cylinder were tested with a burning splinter. The test showed that the gas had remained in the cylinder: it was heavier than air. The student had found that it was not nitrogen. Could it be carbon dioxide? Again some of the gas was prepared and passed into lime water. Immediately a strong turbidity occurred. Thus the conclusion was reached that upon treatment with hydrochloric acid the substance gave off carbon dioxide.

This was the last in the series of assignments which were carried out by the students in the course of the exercise.* However, the exercise itself was not yet finished. Since each member of the class knew only the results of his own work, it was now necessary that he should be informed of the facts his fellow students had discovered. For this purpose the notes taken down during the experiments had to be studied and brief, but complete, reports had to be prepared, which were given to the class. Some of the experiments were important enough to warrant a demonstration, a task which the students who already knew the procedure carried out with great satisfaction.

After the reports and demonstrations had been finished, a table was arranged and the properties of the two substances were listed. The comparison was a surprise to the students. Both crystals and powder formed an aqueous solution which displayed an alkaline character, a slippery feel, and a salty taste. Both substances contained sodium and both gave off carbon dioxide when treated with hydrochloric acid. On the other hand, the original substances looked entirely different. While the crystals became lighter when exposed to the air, the weight of the powder increased. While the crystals when heated gave off large quantities of water, heating of the powder did not produce any change at all.

The students immediately saw the problem. There were two substances, apparently different, but showing so many similarities that a close relationship had to be assumed. How were the two substances related to each other? With great interest the whole class started to attack the problem. Soon a student, who had heated the crystals and determined the percentage of water, made an important discovery. He compared the product of his experiment with the original powder. Both substances seemed to be exactly alike. Could the powder consist of the dehydrated crystalline substance? The idea was examined from all angles. Step by step the students found out how well it agreed with the facts. The investigation went on. Again and again the class studied the properties of the two substances. A number of interesting suggestions were made, some of which offered a practical verification. Thus an experiment was carried out which showed that the crystals

* The last two experiments were performed with both the powder and the crystals.

could be obtained from an aqueous solution of the powder.

The further the discussion advanced, the clearer a definite idea emerged from the various suggestions. Finally, the instructor intervened. The terms "hydrate" and "water of hydration" were introduced, and the complete solution of the problem was given. After a general study of the hydrates and their properties the attention of the class was directed once more to the experiments they had performed. There was still one fact which had to be explained. The students had learned that an alkaline reaction was typical for the solutions of bases. Sodium carbonate,* no doubt, was a salt and not a base. What, then, could be the explanation for the alkaline character of its aqueous solution? This question required special consideration. It led over to the next chapter, the theory of ionization.

* The nature of the anhydrous substance had been deduced in the previous discussion. Here also the formulas of the anhydrous substance and hydrate had been derived and the reaction with hydrochloric acid represented by an equation.

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While the exercise just described is a suitable task for the earlier part of a general chemistry course, there are numerous other topics which permit the application of this method at a more advanced stage of the study. Since, however, the essential features of all these exercises are the same, the description of one example will suffice to demonstrate how well the various aims of elementary laboratory instruction are represented by this method.

CONGO RED. *A* SYNTHESIS ADAPTED *to* SECOND-SEMESTER ORGANIC CHEMISTRY COURSES

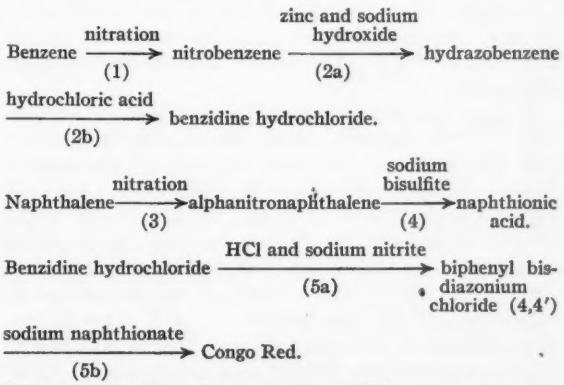
ERNEST R. KLINE

Connecticut State College, Storrs, Connecticut

SERIAL preparations in which the student starts with coal tar crudes and proceeds stepwise to a useful or interesting compound have considerable pedagogical value. The interest developed by them is greater than that developed by an equal number of unrelated preparations, and there is much satisfaction to the student in having, finally and in a single product, the results of progressive synthesis. The chief difficulty in such a series of experiments is the likelihood of running into situations, in one or more of the preparations, where equipment not ordinarily available to undergraduates is required.

The preparation of Congo Red from benzene and naphthalene (moth balls) avoids such difficulties. The materials are inexpensive, no two reactions are strictly identical, and a fairly large number of reactions are required. It is possible to obtain the finished product in less than sixteen hours of work. Twenty hours should be the maximum. The reactions are of the difficulty ordinarily desired for students in their second semester of organic chemistry. The only apparatus required and not ordinarily issued to undergraduates is a small stirring motor. By proper planning of the work, one motor can be made to serve five or six students.

The reactions involved are, in outline, as follows.



The numerals refer to the preparations which are now given.

1. THE PREPARATION OF NITROBENZENE

This preparation is essentially the same as that found in almost any organic laboratory manual. Before starting work with benzene, it is well to recall that the substance is very inflammable and a powerful, although slow-acting, poison when inhaled in quantity.

One hundred and sixty grams of nitric acid (d. = 1.42) and 240 g. of sulfuric acid (d. = 1.83) are mixed and well cooled. This mixture is added in small quantities to 100 g. of benzene (d. = 0.894) contained in a one-liter flask and the benzene immediately shaken. Experience has shown that there is less danger of acid burns if the nitrating mixture is added from a beaker rather than from a dropping funnel. The drop clinging to the lip of the beaker should be removed each time with a piece of moistened cloth. This protects both table tops and hands. The additions are made at such a rate that the temperature never rises above 60° after shaking. Cooling may be resorted to if desired, but care should be taken to keep the reaction going smoothly and not to build up a large excess of unreacted acid. When the acid has all been added and the temperature starts to fall, the mixture is heated to 70°, preferably on a water bath, for at least twenty minutes. It is then cooled and the layers separated. The lower, presumably acid, layer is washed in the separatory funnel successively, with water, sodium carbonate, and again with water. The nitrobenzene is then dried with calcium chloride or, better, with anhydrous magnesium sulfate and fractionally distilled. The portion coming off at 204–7° is collected as product.

2. (*a*) THE PREPARATION OF HYDRAZOBENZENE AND (*b*) ITS IMMEDIATE CONVERSION TO BENZIDINE HYDROCHLORIDE

A mixture of 30 g. of nitrobenzene, 200 cc. of alcohol, and 15 g. of sodium hydroxide dissolved in 35 cc. of water is placed in a liter round-bottomed flask and stirred mechanically. At least 45 g. of zinc dust is added slowly. The exact amount required depends upon its purity and the vigor of stirring. If the reaction becomes too violent and there is danger of loss of alcohol, cooling with water for a few seconds at a time may be necessary. The yellow color should entirely disappear.

Toward the latter end of the addition of zinc, a seven-inch funnel with a short wide stem is fitted with a cork that will close the mouth of a 500-cc. Erlenmeyer flask. A fluted coarse filter paper is placed in the funnel, and about 100 cc. of alcohol is added to the flask. The whole assembly is set on a hot plate so regulated that the alcohol boils gently and condenses in the lower part of the funnel. Two four-inch lengths of 6-mm. tubing placed opposite each other and between the paper and the funnel have been found useful in conducting the vapors of the alcohol and in keeping the filter paper hot.

The now decolorized reduction mixture is transferred hot to the filter and the funnel covered with a watch glass of suitable size. Heating is continued until filtration is complete. The residue is washed with enough boiling alcohol to cover it and the filtrate cooled. The precipitated hydrazobenzene is filtered with suction until air starts to come through the filter. No further attempt is made to dry the product because of its ease of oxidation to azobenzene. A further yield of hydrazobenzene can be obtained by diluting the filtrate with boiled water, but its purity is not so high as that of the first crop.

The solid product is immediately transferred to enough concentrated hydrochloric acid to cover it and allowed to stand fifteen minutes. The mixture is then diluted with water, to three times the original volume, boiled five minutes, and filtered hot. Upon cooling the filtrate, benzidine hydrochloride precipitates. This is filtered off and reserved for experiment 5. The blue color of the product is apparently due to some reaction of the azobenzene which invariably contaminates the hydrazobenzene.

3. THE PREPARATION OF ALPHANITRONAPHTHALENE

The usual procedure in the nitration of solid hydrocarbons is to add the crushed or melted hydrocarbon to the nitrating mixture. This involves an excess of the nitric acid at all times, a condition which is not conducive to high purity in the product. A much better product has been obtained by nitration in acetic acid solution where the proportions of the reactants can be more accurately controlled.

Add 20 g. of naphthalene (moth balls or flakes) to 60 cc. of glacial acetic acid in a 250-cc. Erlenmeyer flask. Complete solution need not take place at this time. Make up a nitrating mixture by pouring 30 cc. of concentrated sulfuric acid into 14 cc. of concentrated nitric acid. Add this mixture, 1 or 2 cc. at a time, to the acetic acid solution of the naphthalene. Mechanical stirring may advantageously be used if the motors are available. Continuous hand shaking is satisfactory, however. Cool to 65° whenever the temperature rises to 75°. After the acids have been added, maintain at 70–80° for a half hour, then cool. Transfer the product into 200 cc. of cold water to complete the precipitation and to remove most of the acids. Filter with suction, and wash several times with cold water. The product can now be melted under hot water and solidified by cooling without stirring to render it non-porous and to make easier the determination of the yield, which should be practically quantitative.

4. THE PREPARATION OF NAPHTHIONIC ACID FROM NITRONAPHTHALENE

In the course of three years over thirty students have prepared Congo Red in this laboratory. Until this year, the conversion of nitronaphthalene to naphthionic acid has been accomplished by reduction with iron, isolation of naphthylamine sulfate, and the conversion of the sulfate to the acid. This last step, while theoretically desirable as an experiment in sulfonation, has caused so much trouble and the yields have been so low that its inclusion seems pedagogically and psychologically undesirable. Therefore, the Piria reaction,[1]

[1] HUNTER, W. H. AND MURRAY M. SPRUNG, *J. Am. Chem. Soc.*, **53**, 1437 (Apr., 1931).

in which both the reduction and sulfonation are accomplished at one operation, has been substituted. The yields are in the range of twenty to thirty per cent. but dependable. The reactants have been calculated on the basis of 1 g. of nitronaphthalene and should be recalculated on the basis of the yield from the preceding preparation.

One gram of nitronaphthalene, 5.7 cc. of 5.2 *M* sodium bisulfite, and 7.15 cc. of water are heated at refluxing until homogeneous except for a possible tarry turbidity. This may require as long as five hours. Mechanical stirring by means of a long-shanked stirrer extending down through the condenser may reduce the time by as much as half. The product is now concentrated by boiling away a quarter of its volume, treated with 2 cc. of concentrated hydrochloric acid, and cooled. The result is a heavy white precipitate which is filtered off and treated with 8.5 cc. of hot water. This dissolves the salts present, but not the naphthionic acid. The latter is removed by filtration with suction, washed with cold water, dried, and the yield determined. The product is sometimes pink.

5. THE PREPARATION OF CONGO RED

The following directions are based on the use of 1 g. of benzidine hydrochloride and 6 g. of naphthionic acid. The proportions should be kept constant but the quantities recalculated to adapt them to the yields at hand.

One gram of benzidine hydrochloride is dissolved in 15 cc. of boiling water or as much more as may be necessary. The solution is cooled quickly to produce small crystals, and ice cubes added until the temperature is 5° or below. One cc. of concentrated hydrochloric acid is then added. One-half gram of sodium nitrite is dissolved in about 10 cc. of water and added by drops to the suspension of benzidine hydrochloride. The latter will go into solution as diazotization proceeds. The addition of nitrite is discontinued when a drop of the well-stirred reaction mixture, after standing for one minute, gives an immediate test with starch-iodide test paper. A large excess of nitrite seems to cause the formation of a quantity of insoluble brown material of undetermined nature later on in the preparation.

Six grams of naphthionic acid is dissolved in as little five per cent. sodium hydroxide as possible. Any considerable excess of alkali should be avoided since amines couple most readily in weakly acid solution. The diazonium solution is run into the sodium naphthionate solution with stirring. After a half hour a solution of 1.38 g. of sodium carbonate is added slowly until the solution is alkaline after thorough stirring. This should cause the product to turn red. The mixture is gradually heated to 80° and maintained there until all evolution of gas ceases.

Before proceeding to the isolation of the product, a piece of cotton cloth is dyed. Boil a six-inch square of white cotton cloth for one minute in enough five per cent. sodium carbonate solution to cover it. Rinse it and boil it for five minutes in some of the Congo Red solution diluted to five times the original volume. Rinse and hang up to dry.

The solution of the dye is combined with the residue from the dye bath and taken to dryness on a steam bath. It is finely pulverized in a mortar and extracted several times with 75 cc. portions of boiling alcohol and the alcohol extracts taken to dryness. This process seems to be preferable to salting out, as a better recovery of product is effected, and the product is less contaminated with sodium chloride.

A METHOD *of* TABULATING *the* REACTIONS *of* QUALITATIVE ANALYSIS

STEPHEN G. SIMPSON

Massachusetts Institute of Technology, Cambridge, Massachusetts

THE following method of tabulating the reactions of qualitative analysis has been used by the writer in his classroom for a period of nearly twenty years. Although the method is not unlike that of Hodge,[1] it offers certain advantages, particularly in taking up less space and being more suitable

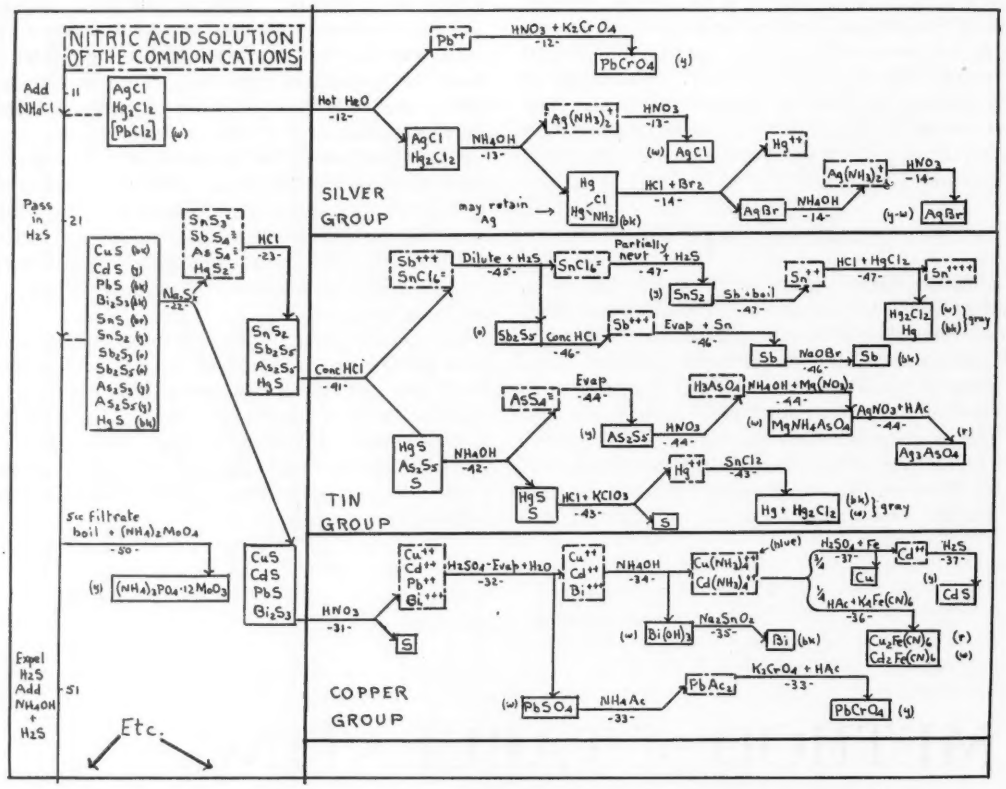
[1] HODGE, H., "An improved method of recording the results of qualitative analysis," J. CHEM. EDUC., **4**, 242–4 (1927).

for blackboard demonstration. It has been found by experience to be a simple, logical way of expressing the various separations and tests, and in addition it presents graphically a bird's-eye view of the entire scheme of analysis. Without such a graphic representation, the student often becomes confused by the many procedures and fails to get a clear picture of the relationships between them. He "cannot see the woods for the trees."

The method employs the following conventions.

1. A procedure within a given group analysis is expressed by a horizontal line. The operation or the essential reagent used is written above the line; the number of the procedure is written below the line.
2. The formation of a precipitate is expressed by an arrow pointing downward.
3. The formation of a gas is denoted by an arrow pointing upward.
4. The formation of a solution is denoted by an arrow pointing diagonally upward to the right.
5. The formation of a residue is denoted by an arrow pointing diagonally downward to the right.
6. Formulas of substances in solution are enclosed by dot-dash lines.
7. Formulas of substances which are precipitates or residues are enclosed by solid lines.
8. Formulas of gases are unenclosed.
9. Colors of precipitates and of certain solutions are denoted by appropriate abbreviations enclosed by parentheses.

The accompanying figure serves merely as an illustration of the principle and covers only the analysis of the silver, copper, and tin groups according to the method of A. A. Noyes. In the classroom, the instructor will find it profitable to sketch the graphic outline on the blackboard in accompaniment to the discussions of chemical principles involved. In addition, the entire qualitative scheme including the analysis of the cations, the analysis of the anions, and the preparation of the solution can be drawn on paper or cardboard even as small as sixteen by twenty inches and used as a laboratory chart. Similarly, the Noyes and Bray scheme for the common and rarer elements can be drawn on two such charts.



LIQUID AMMONIA RESEARCH *in* 1937—*A* REVIEW*

GEORGE W. WATT

The University of Texas, Austin, Texas

AND

NORMAN O. CAPPEL

The Ohio State University, Columbus, Ohio

TO anyone contemplating the use of liquid ammonia as a solvent and reaction medium, the problem of surveying the existing literature should be a relatively simple matter. Publications in the form of monographs (*5–8*) and literature reviews (*9–21*) serve as readily available sources of information and contain a wealth of primary references. These factors greatly facilitate the location of detailed results of specific researches and descriptions of experimental methods. Information regarding the latter may often be best obtained from sources other than the original literature (*5, 15*) since but few authors have provided general treatments of methods and technics.

Many researches involving liquid ammonia have centered about reactions of the alkali amides. These and other researches were reviewed in 1933 by Bergstrom and Fernelius (*19*) who have since published a supplement (*20*) covering the more recent developments. A detailed review of the literature on reactions of solutions of metals in liquid ammonia has also appeared within the past year (*21*). This review is prefaced by a brief discussion of the nature of solutions of metals in ammonia and of the experimental procedures which may be utilized in the study of reactions involving such solutions.

Burgess and Holden (*22*) have shown that silver chloride, iodide, and cyanide are reduced to free silver by solutions of sodium and potassium in liquid ammonia at its boiling point. In addition to the primary reduction reaction, *e. g.*,

$$AgCN + K \rightarrow Ag + KCN,$$

a concurrent reaction between the *reducing* metal (Na or K) and ammonia may also occur,

$$K + NH_3 \rightarrow KNH_2 + \tfrac{1}{2}H_2$$

The extent to which this latter reaction occurs depends upon the catalytic activity of the *reduced* metal (Ag) which is in turn conditioned by the nature of the salt reduced and by the reducing metal used. Thus, silver produced by the reduction of silver cyanide was found to be more active than from the chloride or iodide. Further, silver obtained by using potassium as the reducing metal was found more effective as a catalyst than that produced when sodium was employed.

Both silver cyanate and thiocyanate have been reduced to free silver and alkali cyanate or thiocyanate by either sodium or potassium. While the cyanate group is stable in the presence of excess alkali metal, the thiocyanate group is partially reduced to sulfide and cyanide. When, however, a solution of calcium is used as the reducing agent (*23*) the reduction of the thiocyanate group is complete

$$2AgSCN + Ca \rightarrow 2Ag + Ca(SCN)_2,$$
$$Ca(SCN)_2 + Ca \rightarrow 2CaS + Ca(CN)_2,$$
$$Ca + 2NH_3 \rightarrow Ca(NH_2)_2 + H_2$$

Using an *excess* of calcium, an appreciable reduction of the cyanate group was also observed. Silver iodide and cyanide have been shown to undergo reduction by means of calcium more readily and to yield more highly reactive silver (pyrophoric) than when the alkali metals are used. Thus, evidence has been presented which shows that calcium in liquid ammonia is a more effective reducing agent than sodium or potassium.

The action of liquid ammonia at low temperatures upon borine carbonyl, BH_3CO, has been shown to result in the formation of the compound, $BH_3CO(NH_3)_2$ (*24*). This substance reacts with sodium in liquid ammonia at $-77°$ to liberate two equivalents of hydrogen, thus indicating the presence of two ammonium ions. Borine trimethylammine, $BH_3N(CH_3)_3$, however, has been found to be stable in the presence of sodium in liquid ammonia at low temperatures.

A method for the preparation of arsine has recently been described by Johnson and Pechukas (*25*). Yields of from sixty to ninety per cent. were obtained by means of the following reactions conducted in liquid ammonia solution.

$$3Na + xAs \rightarrow Na_3As_x$$
$$Na_3As_x + 3NH_4Br \rightarrow 3NaBr + 3NH_3 + AsH_3 + (x - 1)As$$

Although arsine is only slightly soluble in liquid ammonia, it has been shown to react with solutions of sodium and potassium at $-78°$C. to form alkali dihydrogen arsenides (*26*),

$$K + AsH_3 \rightarrow KAsH_2 + \tfrac{1}{2}H_2$$

the product $KAsH_2$, for example, being analogous to the alkali amide, KNH_2. This arsenide has also been

* For earlier papers in this series see references (*1–4*).

formed by the action of potassium amide on arsine in ammonia at −78°,

$$KNH_2 + AsH_3 \rightarrow KAsH_2 + NH_3$$

Arsine may be regenerated by treating the dihydrogen arsenide with ammonium bromide (an acid in liquid ammonia),

$$KAsH_2 + NH_4Br \rightarrow KBr + NH_3 + AsH_3$$

The following reactions have also been carried out in liquid ammonia at −78°.

(1) $KAsH_2 + CH_3Cl \rightarrow KCl + CH_3AsH_2$
(2) $CH_3AsH_2 + K \rightarrow CH_3AsHK + {}^1/_2H_2$
(2a) $CH_3AsHK + NH_4Br \rightarrow KBr + CH_3AsH_2 + NH_3$

Bergstrom (*27*) has reported that the reaction between cerous iodide and potassium amide in liquid ammonia at 0° results not in the anticipated cerous amide, $Ce(NH_2)_3$, but rather in the crystalline ammonobasic iodide, $CeI_3 \cdot Ce(NH_2)_2 \cdot 10NH_3$. Deammonation of this product *in vacuo* at 150–80° yielded $CeI_3 \cdot Ce(NH)NH_2$. Juza (*28*) has discussed the structure, energy relations, and methods of preparation of the amides of groups I and II on the basis of their melting points, conductivity, molecular volume, and heats of formation.

Bailar and co-workers (*29*) have found that a Walden inversion occurs during the formation of diaminodiethylenediaminocobaltic chloride from *l*-dichlorodiethylenediaminocobaltic chloride, $[Coen_2Cl_2]Cl$, and liquid ammonia. When the diamino compound is formed at or below the boiling point of ammonia, it is levorotatory. When, however, the conversion of the dichloro to the diamino compound is effected at or above 25°, the product is dextrorotatory. The diamino compound so formed was found to consist largely of the *cis* form. Nickel carbonyl has been found to be practically insoluble in and unreactive toward liquid ammonia at its boiling point (*30*).

In connection with his studies on the constitution of the erythro- and rhodochromium salts, Jensen (*31*) has investigated their behavior toward liquid ammonia. Normal rhodochromium bromide, when treated with liquid ammonia at room temperature, was found to be converted into the basic rhodochromium salt,

$$[(NH_3)_5Cr{-}OH{-}Cr(NH_3)_5]Br_5 \rightarrow [(NH_3)_5Cr{-}O{-}Cr(NH_3)_5]Br_4$$

Basic erythrochromium bromide, when similarly treated, was rearranged into the basic rhodochromium bromide,

$$\left[(NH_3)_5Cr{-}NH_2{-}Cr\begin{matrix}(NH_3)_4\\(OH)\end{matrix}\right]Br_4 \rightarrow [(NH_3)_5Cr{-}O{-}Cr(NH_3)_5]Br_4$$

Basic erythrochromium bromide, when treated with a saturated solution of ammonium chloride in liquid ammonia at −33°, was converted into the normal rhodo salt,

$$\left[(NH_3)_5Cr{-}NH_2{-}Cr\begin{matrix}(NH_3)_4\\(OH)\end{matrix}\right]Br_4 \rightarrow [(NH_3)_5Cr{-}OH{-}Cr(NH_3)_5]Br_5$$

In general, liquid ammonia was found to convert erythro salts into rhodo salts. When, however, either dilute or concentrated aqueous ammonia is used the reverse transformation takes place.

The action of liquid ammonia on iodine pentoxide (*32*) has been found to result in the formation of a substance which explodes when warmed to 0°. It is believed that ammonium amidoiodate is first formed and that this substance breaks down into nitrogen iodide and water on warming. The sodium salt, which was found to be much more stable, was formed together with sodium iodate by the action of sodium amide in liquid ammonia on iodine pentoxide.

A quantitative study of the heat developed during the ammonation of superphosphate and superphosphate mixtures with liquid ammonia has recently been described (*33*). The complete ammonation of ordinary superphosphate may be represented by the equations,

(1) $H_3PO_4 + NH_3 \rightarrow NH_4H_2PO_4$
(2) $Ca(H_2PO_4)_2 \cdot H_2O + NH_3 \rightarrow CaHPO_4 + NH_4H_2PO_4 + H_2O$
(3) $NH_4H_2PO_4 + CaSO_4 + NH_3 \rightarrow CaHPO_4 + (NH_4)_2SO_4$
(4) $2CaHPO_4 + CaSO_4 + 2NH_3 \rightarrow Ca_3(PO_4)_2 + (NH_4)_2SO_4$

The apparatus and experimental procedures employed in the measurement of the heat effects accompanying these and other reactions have been described. The measured values for the heat of ammonation of monocalcium phosphate, ordinary superphosphate, and double superphosphate were found to be in good agreement with the calculated values. The results of this investigation have been applied in determining the extent to which heat developed in these ammonation reactions may be utilized in the drying and granulation of certain fertilizer mixtures.

Vasil'ev and co-workers (*34*) have described a method for the preparation of sodium carbonate in liquid ammonia from sodium chloride and carbon dioxide,

$$CO_2 + 2NH_3 \rightarrow NH_4CO_2NH_2$$
$$NaCl + NH_4CO_2NH_2 \rightarrow NH_4Cl + NaCO_2NH_2$$

This reaction is explained on the basis of the ternary system, ammonium chloride–ammonium carbamate–ammonia. Ammonium carbamate is formed rapidly when carbon dioxide is passed into liquid ammonia. This compound reacts with the sodium chloride to form sodium carbamate and ammonium chloride. The increase in solubility of ammonium carbamate in the presence of ammonium chloride shifts the equilibrium toward the formation of sodium carbamate, the least soluble salt under these conditions. Sodium carbonate of not less than ninety-nine per cent. purity is obtained by heating sodium carbamate with steam at 250–300°. The process was found to be most efficient when run for one hour at 20°, using 1.93 parts by weight of ammonia to 1.0 part of sodium chloride. The yield under these conditions was found to be ninety-three per cent. Bolotov and co-workers have extended their studies (*35*) on the preparation of urea from carbon dioxide and ammonia. The optimum conditions for the synthesis of urea was found to be a temperature of 165–75°, one

hundred per cent. excess ammonia, a pressure of 170–200 atmospheres, and a period of heating of 1.25–1.5 hours. A sixty to sixty-eight per cent. yield of urea was obtained under these conditions.

Moureu and Wetroff (*36*) have found that the ammonolysis of phosphorus trichloride proceeds as indicated by the following equations.

$$PCl_3 + 6NH_3 \rightarrow 3NH_4Cl + P(NH_2)_3$$
$$P(NH_2)_3 \rightarrow PNHNH_2 + NH_3$$
$$2PNHNH_2 \rightarrow P_2(NH)_3 + NH_3$$

They have reported that the imide, $P_2(NH)_3$, undergoes thermal decomposition (700°C.) leading to the formation of a nitride, P_4N_6;

$$2P_2(NH)_3 \rightarrow P_4N_6 + 3H_2,$$

which, upon being heated to 800° under reduced pressure, loses nitrogen,

$$P_4N_6 \rightarrow (PN)_n + N_2$$

These results are in conflict with earlier views which held that thermal decomposition of the imide, $P_2(NH)_3$ resulted in the formation of phospham, PN_2H. Renaud (*37*), supporting this latter view, has criticized the conclusions drawn by Moureu and Wetroff who in turn have defended their position with regard to the formation of the nitride, P_4N_6 (*38*). Numerous properties and reactions of the compound, $(OPN)_n$, have been reported by Wetroff (*39*). This substance was obtained by heating the products resulting from the action of liquid ammonia on $POCl_3$. The ammonolysis of tantalum pentachloride at the boiling point of liquid ammonia has been shown to occur in accordance with the following equation (*40*).

$$TaCl_5 + 17NH_3 \rightarrow Ta(NH_2)_2Cl_3 \cdot 7NH_3 + 2NH_4Cl \cdot 3NH_3$$

Various properties of the resulting heptammine of tantalum trichlorodiamide have been recorded.

Vapor-tension measurements on the system $TaCl_5$–NH_3 over the temperature range, −81.5 to 136°, have shown that tantalum pentachloride is not ammonolyzed at temperatures below 0°, but forms ammonates with 12.0, 10.0, and 7.0 moles of ammonia per mole of salt (*41*). At 0°, ammonolysis was found to take place, probably in accordance with the following equation.

$$TaCl_5 \cdot 7NH_3 \rightarrow 2NH_4Cl + Ta(NH_2)_2Cl_3 \cdot 3NH_3$$

The ammonolysis product is believed to subsequently undergo further ammonation. At 78° this product was found to lose ammonia and to become yellow in color. Further heating results in the deepening of the color and the separation of ammonium chloride. It is of interest to compare these data with results obtained by Moureu and Hamblet (*40*), which indicate that $TaCl_5$ is ammonolyzed at the boiling point of liquid ammonia. A tensiometric investigation of the ammonates of ammonium chloride, bromide, and iodide between −82 and 17.5° has revealed the existence of the following compounds: $NH_4Cl \cdot 3NH_3$, $NH_4Br \cdot 3NH_3$, $NH_4I \cdot 5$, 4, 3, 2, and $1NH_3$ (*42*). The triammonates of ammonium chloride and bromide decompose below −29°, while the ammonates of ammonium iodide all decompose below 0°. The heat of formation of the ammonates of ammonium iodide was found to decrease with an increase in the number of coördinated ammonia molecules. By means of vapor-tension measurements over the indicated temperature ranges, Klemm and Frischmuth (*43*) have provided evidence for the existence of ammonates of $ReCl_3$ containing 14, 7, and 6 molecules of ammonia (−78° to 0°), and of $ReBr_3$ containing 20, 14, 9, and 7 molecules of ammonia (−78° to 21°). These halides were found to be appreciably ammonolyzed above 100°C., while $ReCl_5$ was found to undergo considerable ammonolysis at even lower temperatures. Similar investigation of the systems UCl_4–NH_3 (−78.5° to 184°) and UO_2Cl–NH_3 (−78° to 130°) has indicated the existence of the following ammonates (*44*). $UCl_4 \cdot$-10, 5, 4, and $3NH_3$; $UO_2Cl_2 \cdot 10$, 5, 4, 3, 3, and $1NH_3$. No evidence was found to indicate the formation of a previously reported octaammonate of UCl_4. The ammonates of higher ammonia content were found to be stable only at low temperatures and over a much smaller temperature interval than in the case of the more stable lower ammonates. The heat of formation was found to decrease with increase in the number of coordinated ammonia molecules which confirms the assumption that the first ammonia molecules are more firmly held.

Ormont (*45*) has discussed the rôle that the *s*-electrons (unshared electrons of a completed octet) play in the formation of intermolecular compounds and complex ammonates in liquid ammonia, and in the formation of solutions in this solvent. The quantum characteristics of the valency electrons of the central atom and the steric factor are used as a basis for the classification of the complex ammonates. The results of different workers on the band spectra of liquid ammonia, its solutions, and solutions of various ammonium salts in liquid ammonia are in complete agreement with the view that has been developed.

A study has been made of the physico-chemical properties of the binary system $NaNO_2$–NH_3 (*46*). Tables showing the solubility (−77.7° to 172°), specific gravity of solutions at 20°, tension of the saturated vapor (−27.5° to 36.5°), and electrical conductivity (−30° to 40°) are presented. Over the temperature interval −87.5° to −64° the solid phase existing in equilibrium with the saturated solution is the ammonate, $2NaNO_2 \cdot$-NH_3. The electrolysis of sodium nitrite in liquid ammonia was found to result in the formation of sodium amide and hydrogen at the cathode and ammonium nitrite and nitrogen at the anode. Pleskov (*47*) has measured the conductivities of solutions of sodium chloride and potassium nitrate in liquid ammonia at −40° and to a dilution of 3×10^{-7} mole/liter. The theory of Debye, Hückel, and Onsager could be applied only at concentrations below 4×10^{-6} *N*. The equivalent conductivities obtained by extrapolation were found to be in good agreement with the values calculated according to the theory of Fuoss and Kraus.

The electrolytic valve action of tantalum and aluminium in liquid ammonia have been measured (*48*). No rectifying effect was observed with tantalum using the following electrolytes: sodium nitrate, sodium tetraborate, boric acid, potassium iodide and a compound given the composition, $K_2Ag_2(CN)_2$. Aluminum was found to show an imperfect valve action in liquid ammonia solutions of boric acid and sodium tetraborate. No rectifying effect was observed in the case of copper, magnesium, and iron.

Wooster (*49*) has shown that the conductance of sodium benzophenone in liquid ammonia may be described quantitatively by assuming the presence of the following equilibria.

$$[(C_6H_5)_2CO]Na \rightleftharpoons [(C_6H_5)_2CO]^- + Na^+$$

$$[(C_6H_5)_2CO]Na + [(C_6H_5)_2CO]^- \rightleftharpoons Na[(C_6H_5)_2CO]_2^-$$

$$2[(C_6H_5)_2CO]Na \rightleftharpoons \begin{matrix}(C_6H_5)_2CONa\\ |\\ (C_6H_5)_2CONa\end{matrix}$$

The normal electrode potentials of lithium, rubidium, and calcium in liquid ammonia have been determined by Pleskov (*50*). The measurements were carried out at −35°C. using amalgam electrodes, with lead in a 0.1 normal solution of lead nitrate in liquid ammonia as a normal electrode. Their values, referred to the hydrogen electrode as zero, as well as the corresponding potentials in water are given in Table 1. The values for the other alkali metals are included for the sake of comparison.

TABLE 1

Metal	*Li*	*Na*	*K*	*Rb*	*Cs*
E_{NH_3}	−2.99	−2.59	−2.73	−2.68	−2.39
E_{H_2O}	−3.02	−2.71	−2.92	−2.93	−2.77
$E_{NH_3} - E_{H_2O}$	0.03	0.12	0.19	0.25	0.39

A study of the near infra-red absorption spectrum of liquid ammonia at −75°C. has resulted in the measurement of eleven lines between 6370 and 9370 Å. (*51*). The classification of these lines and their relationship to the Raman lines has been discussed in some detail. Vol'kenshtein (*52*) has studied the Raman spectra of mercuric cyanide in liquid ammonia corresponding to the compositions, $Hg(CN)_2 \cdot 6NH_3$ and $Hg(CN)_2 \cdot 2 3NH_3$. The frequency attributed to the CN group was found to be lowered in liquid ammonia.

A study has been made of the solubility of potassium bromide in liquid ammonia over the temperature interval −84° to 98°, the vapor tension and conductivity of saturated solutions from −31° to 30°, and the 20° isotherm for specific gravity (*53*). The electrolysis of potassium bromide in liquid ammonia was found to result in the formation of potassium amide at the cathode and ammonium bromide at the anode,

$$6KBr + 14NH_3 \rightarrow 6NH_4Br + 6KNH_2 + 3H_2 + N_2$$

The decomposition voltage at −35° was found to be 3.45–3.6 volts.

Distanov (*54*) has determined the solubility of sodium bromide in liquid ammonia over the temperature range, −22° to 183°. The solubility of sodium bromide was found to increase considerably between −22° and 13°, to remain constant between 13° and 75°, and then to decrease above 75° with a critical point at 183°. Wiebe and Gaddy (*55*) have measured the solubility of hydrogen in liquid ammonia at 0°C. and at pressures up to 1000 atmospheres. Over the same pressure range the solubility of nitrogen has been measured at 0°, 50°, 75°, 90°, and 100°. For the system ammonia–nitrogen, critical points were observed at 90° and about 600 atmospheres and at 100° and approximately 375 atmospheres.

In a recent paper, Overstreet and Giauque (*56*) have provided values for the physical constants of ammonia listed in Table 2, as well as vapor pressure data over the range −96.18° to −31.5°C. and values for the heat capacity of ammonia over the range −258.06° to −33.42°C. Their experimental methods and results have been critically compared with those of earlier workers. This paper is recommended as a source of primary references.

TABLE 2

Boiling point, °C.	−33.42
Melting point, °C.	−77.74
Mean heat of fusion, cal./mole	1351.6
Heat of vaporization at B.P., cal./mole	5581
Entropy of gas at B.P., cal./deg. per mole	44.13
Absolute entropy, cal./deg. per mole	55.22

Shatenshtein (*57*) has pointed out the important rôle played by the solvent in the establishment of acid-base equilibria. The increase in strength of weak acids in liquid ammonia is shown by the catalytic activity of glucose, acetamide, urea, carbazole, benzamide, α-cyanoacetamide, phenol, and formamide in the ammonolysis of santonine, the shift in the color interval of acid-base indicators, and the existence of indicators not known as such in aqueous solution. In connection with his studies on acid catalysis, Shatenshtein (*58*) has investigated the ammonolysis of ethyl tartrate and desmotroposantonine in the presence of various ammonium salts by the polarimetric method. Ethyl tartrate was converted into the diamide while the end product of the reaction between desmotroposantonine and liquid ammonia is believed to be the amide of desmotroposantoninic acid. The reactions, which were effected in sealed tubes at 20°, were found to be markedly catalyzed by ammonium salts, the catalytic activity increasing with concentration in the following order.

$$Cl^- > Br^- > NO_3^- > I^- > ClO_4^-$$

A study has been made (*59*) of the effect of ammonium salts upon the ammonolysis at 0° and −33° of diethyl malonate to malonamide in liquid ammonia. It is believed that the reaction proceeds through an intermediate product, ethyl malonamate. The results showed that, within the limits of experimental error of the method used, equivalent concentrations of the various salts used were equally effective in the conversion of the ester to the diamide. The reaction was also shown to be autocatalytic in nature, since the reaction

was catalyzed by malonamide, one of the products of the reaction.

Evidence in support of the view that inulin dissolved in liquid ammonia behaves as a gelating colloid has been presented by Bergstrom and Gilmore (*60*). Upon standing, inulin precipitates from its solutions in ammonia forming a translucent gel. Further, it exhibits the Tyndall effect and will not diffuse through a cellophane membrane permeable to sucrose.

At a meeting of the Cellulose Division of the American Chemical Society in New York on April 25, 1935, Barry, Peterson, and King presented a paper in which they described their work on the interaction of cellulose and liquid ammonia. A detailed account of this work did not appear in the literature until February of 1936 (*61*). Meanwhile, Hess and Trogus, in a paper submitted for publication on September 27, 1935 (*62*), described briefly the work which they had already done on this same problem. The results provided by these independent investigations are notable for their lack of agreement both with respect to experimental observations and interpretations. In a paper submitted for publication on February 20, 1937, Clark and Parker (*63*) have described their attempts to clear up certain inconsistencies in and questions raised by the above-mentioned investigations. With regard to the extent to which native cellulose and mercerized cellulose are swollen in the presence of liquid ammonia at or near −75°C., Clark and Parker have found that the swelling results in a much greater increase in the size of the 101 interplanar distance than was reported by the earlier investigators. They have also shown that the 101 planar distance decreases progressively as the ammonia is allowed to evaporate from the swollen fibers. Treatment of swollen ammonia-native cellulose with concentrated aqueous ammonia resulted in complete reversion to native cellulose whereas ammonia-mercerized cellulose, when similarly treated, underwent reversion only to the extent of seventy per cent. When ammonia was allowed to evaporate from the swollen fibers a modification designated as cellulose-III was obtained. The properties of this material have been studied extensively, but the details cannot be presented here because of lack of space. It was observed during this investigation that commercial cellulose acetates are saponified by liquid ammonia.

In addition to new information supplied by the studies made by Clark and Parker, they have confirmed certain observations recorded by Barry and co-workers as well as certain of the results obtained by Hess and Trogus. Since all of these workers have observed the ease with which the swollen fibers lose ammonia when out of contact with the liquid, Clark and Parker have raised the significant question as to whether the swelling of the fibers actually involves compound formation between cellulose and ammonia. In a paper submitted for publication on July 5, 1937, Hess and Gundermann (*64*) have described further researches which they believe to show that, in the presence of liquid ammonia, cellulose forms two *ammonates*, NH_3-cellulose-I, and NH_3-cellulose-II. It is believed that these may be either enantiotropic modifications or ammonates of different ammonia content. NH_3-cellulose-II, which is stable only at low temperatures, and the more stable NH_3-cellulose-I may be reversibly changed from one form to the other between −20° and −30°C. Both substances yield cellulose-III by loss of ammonia. Hess and Gundermann have found that cellulose-III shows a marked resemblance to hydrated cellulose but that unlike the latter, cellulose-III may be converted to natural cellulose by treatment with water in an autoclave at 200°C. In all probability, further contributions to the study of the interaction of cellulose and liquid ammonia will be forthcoming.

The results of an extensive investigation of the ammonolysis of organic halides have been described by von Braun and co-workers (*65*). All reactions were effected in sealed glass tubes or steel bombs using an excess of liquid ammonia at room temperature. In general, relatively high yields of primary amines (along with lesser quantities of secondary and tertiary amines) may be obtained readily in this manner, while only poor yields of primary amines result when aqueous or alcoholic ammonia is used. Among halides of the type RCH_2Cl, where R is an aromatic or heterocyclic simple or condensed ring system, the yield of primary amine increases with increase in the molecular weight and irrespective of the complexity of the substituent, R. Among alkylene dihalides, the course of the reaction is conditioned by the relative proximity of the halogen atoms. Thus, 1,3-dibromopropane gave 1,3-diaminopropane and chain homologues of the type $NH_2(CH_2)_3[NH(CH_2)_3]_nNH_2$. Analogous products were obtained from 1,2-dibromoethane. 1,5-Dibromopentane yielded mainly bispiperidinium bromide, $C_5H_{10}N(Br)C_5H_{10}$. Small amounts of amylenylpiperidine, cadaverine, and piperidine were also identified. 1,4-Dibromobutane reacted with liquid ammonia to form analogous products. However, with higher molecular weight dihalides, such as 1,11-dichloroundecane, the tendency toward the occurrence of ring closure was not observed and the alkylene diamines were the principal products. This work clearly demonstrates the superiority of liquid ammonia over aqueous or alcoholic ammonia in the conversion of organic halides to the corresponding primary amines. Ammonolytic reactions of this type have been utilized in the preparation of spermidine, $NH_2(CH_2)_4NH(CH_2)_3NH_2$, and analogous substances from the corresponding halogen compounds (*66*).

Some twenty-five years ago, Chablay reported that the interaction of the lower alkyl halides and sodium amide in liquid ammonia at its boiling point resulted in the production of unsaturated hydrocarbons in yields which increased with increase in the molecular weight of the halide. Recently, it has been shown that this generalization is unwarranted (*67*). In reactions conducted at or below −34°, the following yields of primary amine were obtained from the indicated halides. Secondary amine formation became appreciable only when an excess of halide was employed. Using iso-

amyl bromide, but little variation in yields was observed when the reaction temperature was varied between −34° and −70°C. Sodium amide (prepared in liquid ammonia!) proved superior to the amides of calcium and barium which appear to be relatively unreactive, and to

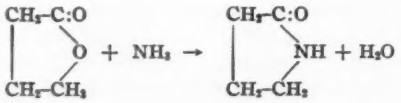
TABLE 3

Halide	*Yield, %*
Isoamyl Chloride	30–40
Isoamyl Bromide	50–60
Isoamyl Iodide	50–60
n-Hexyl Bromide	75
2-Ethylbutyl Bromide	10

potassium amide which appears to favor alkene formation. The production of amines by reactions of this type could not be accomplished in solvents other than liquid ammonia. The ammonolysis of α-phenylethyl chloride by liquid ammonia in a sealed tube over a period of six weeks at room temperature has been shown to result in the formation of the corresponding primary amine (*68*).

In connection with a study of the synthesis of phenanthridine derivatives, 9-phenyl- and 9-(α-naphthyl)-9-fluorylamines have been prepared readily by the ammonolysis of the corresponding 9-aryl-9-chlorofluorenes (*69*). The reactions were effected under pressure above room temperature over a period of several hours. Greater difficulty attended the preparation of the analogous 9-methyl compound. It was obtained by heating a solution of 9-methyl-9-bromofluorene in a mixture of toluene and liquid ammonia for twenty hours at 75°. Jansen and Wibaut (*70*) have prepared 2-amino- and 3-aminoquinolines in good yields by the treatment of the corresponding bromides with liquid ammonia in the presence of copper powder as a catalyst. The reactions were carried out in sealed tubes at a temperature of 70° over a period of many hours. In the absence of the copper catalyst 2-bromoquinoline was found to be only slowly ammonolyzed.

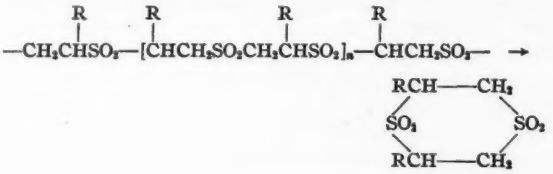
The formation of 3-bromosalicylamide by the ammonolysis of methyl 3-bromosalicylate has recently been reported (*71*). The tribenzenesulfonate of pyrogallol has been shown to undergo partial ammonolysis with the formation of the 1,3-dibenzenesulfonic ester when treated with liquid ammonia in a sealed tube at room temperature (*72*). Under similar conditions, the action of liquid ammonia on γ-butyrolactone at 200° has been shown to result in a sixty-four per cent. yield of α-pyrrolidone (*73*).



Similarly, a seventy-four per cent. yield of 5-methyl-2-pyrrolidone has been obtained by treatment of γ-valerolactone with zinc chloride and ammonia.

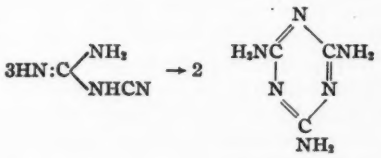
In a previous review (*4*) reference was made to the ammonolysis of vitamin B_1 and to the reduction, by means of a solution of sodium in liquid ammonia, of the amidosulfonic acid derived from the vitamin. More recently an account of the experimental details of this significant work has appeared in the literature (*74*). Ammonolysis of the vitamin was accomplished by allowing it to react with anhydrous liquid ammonia at room temperature over a period of forty-two hours. In connection with their studies on the structure of gossypol (the yellow pigment present in cottonseed), Miller and Adams (*75*) have found that both gossypol and its dehydration product, anhydrogossypol, react with liquid ammonia at its boiling point to form a diamino derivative.

It has been shown that certain polysulfones derived from olefins of the type $RCH{:}CH_2$ are converted into cyclic disulfones by solution in liquid ammonia (*76*):



Polymeric sulfones derived from propylene, 1-pentene, 1-octene, 1-nonene, and styrene were thus converted to the corresponding cyclic structures. Polysulfones which are insoluble or difficultly soluble in liquid ammonia apparently are not similarly degraded.

Melamine has been produced in eighty per cent. yield by heating dicyanodiamide with twice its weight of liquid ammonia in an autoclave at 155° for two hours (*77*).



Nitro- and nitroso-guanidine have been found to be soluble in and unreactive toward liquid ammonia and solutions of sodium amide in the same solvent (*78*). The reduction of nitroguanidine by means of sodium in liquid ammonia is apparently a complex reaction, only cyanamide (ten per cent.) and nitrogen (thirty per cent.) having been identified as reduction products. When, however, the reduction reaction is carried out in the presence of ammonium chloride or ammonium acetate (acids in liquid ammonia) yields of aminoguanidine up to seventy per cent. may be obtained depending upon the concentration of ammonium salt used. On the basis of the foregoing study and other considerations, the use of liquid ammonia as a solvent medium for catalytic hydrogenation reactions is being investigated.

Although toluene is not attacked by sodium in anhydrous liquid ammonia solution, it has recently been found that upon addition of water, the toluene is apparently reduced to an unsaturated liquid product (*79*). Further work is being done in an effort to elucidate the mechanism of reduction processes involving alkali metals and water. It has been pointed out that in the

reduction of organic substances by means of solutions of alkali metals in liquid ammonia, toluene is often used as a diluent for the purpose of increasing the solubility of the organic material. The excess alkali metal remaining after completion of such reactions is usually determined by measuring the hydrogen evolved upon addition of water, ammonium chloride, or an ammonolysis catalyst. Since water induces a reaction between the alkali metal and toluene, either ammonium chloride or an ammonolysis catalyst (oxides of iron, etc.) should be used in determining the excess metal.

Studies on the action of solutions of sodium in liquid ammonia at its boiling point on *ortho*, *meta*, and *para* substituted diphenyl ethers has shown that such ethers undergo rapid and quantitative cleavage at the carbon-oxygen linkage (*80*, *81*).

$$ROR + 2Na^+ + 2e^- \rightarrow R^- + RO^- + 2Na^+$$
$$R^- + NH_3 + Na^+ \rightarrow RH + NH_2^- + Na^+$$

The presence of the following substituent groups, listed in order of increasing effectiveness, renders the ether less susceptible to cleavage: *o*-CH_3, *m*-CH_3, *m*-NH_2, *p*-CH_3, *p*-OCH_3, *o*-NH_2, and *p*-NH_2. Cleavage is favored by the groups, *m*-OCH_3, *o*-OCH_3, *m*-CO_2Na, *o*-CO_2Na, and *p*-CO_2Na, also listed in order of increasing effectiveness. Triphenylmethane and *o*-cresol (fifty-four per cent.) have resulted from the cleavage of *o*-tolyltriphenyl ether by means of a solution of sodium in liquid ammonia at $-33°$ over a period of seven days (*82*). Similarly, over a period of five and one-half days, benzyl phenyl ether yielded bibenzyl and phenol (forty-eight per cent.) while diphenyl ether gave a fifty per cent. yield of phenol in four and one-half days. Diisoamyl ether was found to be very stable toward cleavage and was, for the most part, recovered unchanged after treatment with sodium in liquid ammonia for five and one-half days. A preliminary study (*83*) has been made of the cleavage of a number of ethers of cellulose by sodium in liquid ammonia. It has been pointed out that cleavage may take place in two directions.

(1) $\text{Cell-O-R} + 2Na^+ + 2e^- \rightarrow \text{Cell-O}^- + R^- + 2Na^+$
(2) $\text{Cell-O-R} + 2Na^+ + 2e^- \rightarrow \text{Cell}^- + \text{R—O}^- + 2Na^+$

The benzyl ester of cellulose was found to give bibenzyl and cellulose. Methylcellulose (41.15 per cent. OCH_3) reacted similarly, but evidence showed that cleavage must take place partly according to (2). Triacetyl cellulose was found to react with two atoms of sodium for each acetyl group. This reaction is being further investigated. While 2-acetoxy-1-alkenes are not ammonolyzed by liquid ammonia at $-34°$, they undergo cleavage when treated with solutions of sodium in ammonia, probably in the following manner (*84*).

$$CH_3C(:O)OC(R):CH_2 + 2Na \rightarrow CH_2:CHONa + NaOC(R):CH_2$$

Cleavage of esters of this type has also been accomplished through the action of solutions of iodine in liquid ammonia.

The preparation of a number of acetylenic ethers of the type, $ROC_2H_4C{\equiv}CH$, has been described (*85*). Solutions of sodium acetylide in liquid ammonia at its boiling point were treated with the appropriate alkoxy bromides. The synthesis of 1-pentadecyne by the interaction of 2-bromo-1-pentadecene and sodium amide in liquid ammonia solution has been reported (*86*).

The formation of alkali and alkaline earth metal acetylides in liquid ammonia and their subsequent use in the preparation of mono- and dialkyl-acetylenes through interaction with alkyl halides or sulfates has been studied in detail by Nieuwland and co-workers (*87*). The acetylides of Na, K, Ba, and Ca were found to be of approximately equal reactivity. The occurrence of side reactions and the influence of widely varied experimental conditions upon the yields and purity of the substituted acetylenes have been studied thoroughly. This paper may be consulted with profit by anyone contemplating the utilization of reactions of the type in question. Bried and Hennion (*88*) have shown that the reactions

$$HC{\equiv}CNa + RX \rightarrow RCH{=}CH + NaX$$
$$RCH{=}CH + NaNH_2 \rightarrow RC{\equiv}CNa + NH_3$$
$$RC{\equiv}CNa + RX \rightarrow RC{\equiv}CR + NaX$$

leading to the formation of *sym*-dialkylacetylenes may be carried out simultaneously, thus effecting a considerable saving of time. By allowing the above reactions to occur successively in the same solution, this method may be adapted to the preparation of *unsym*-dialkylacetylenes. In neither case is the isolation of intermediate products necessary. Alkyl bromides were found more suitable alkylating agents than either the corresponding chlorides or sulfates. Heretofore, the only alkylating agents used in reactions of this nature in liquid ammonia solutions have been the alkyl halides and methyl and ethyl sulfates. Recent work has shown that other alkyl esters of sulfuric acid as well as certain soluble esters of *p*-toluenesulfonic acid may also be similarly employed (*89*). Thus, sodium salts of acetylene, phenol, and certain alcohols were prepared in liquid ammonia at its boiling point and treated with the appropriate ester. Esters of acetic and phosphoric acids were found unsuitable as alkylating agents.

The complete methylation of potato starch has been accomplished by Hess and Lung (*90*). Partially methylated starch (42–3 per cent. OCH_3) was treated with sodium in liquid ammonia at $-70°$C. in the presence of anisole. The ammonia was then removed and the sodium salt treated with methyl iodide in anisole. This treatment resulted in complete methylation (45.6 per cent. OCH_3) whereas the more common procedures resulted in only partial completion of the process. Schlubach and Loop (*91*) have applied this method to the methylation of galactogen. Methylation with dimethyl sulfate resulted in a methoxyl content of 41.4 per cent. When this partially methylated product was treated as described above, the methoxyl content was increased to 44.7 per cent. In a similar manner, Freudenberg and Boppel (*92*) have succeeded in methylating cellulose to a methoxyl content of 44–6 per cent. (calcd.,

45.5 per cent.). Cotton or ramie previously methylated to the extent of 42–3 per cent. OCH_3 was suspended in liquid ammonia and treated with sodium at −40° over a period of six hours, after which an excess of methyl iodide was added. On the other hand, an attempt to methylate benzylideneglucosamine by treatment in liquid ammonia with potassium and methyl iodide has resulted in a product containing only 2.3 per cent. OCH_3 (*117*).

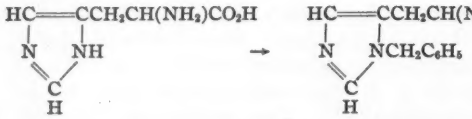
Hexomethionine (ε-methylthiol-α-aminocaproic acid) has been prepared in eighty-five per cent. yield by the reduction of hexocystine [bis(ε-amino-ε-carboxyamyl) disulfide] with sodium in liquid ammonia followed by the addition of methyl iodide to the reduction product (*93*).

$$[HO_2CCH(NH_2)(CH_2)_4]_2S_2 + 2Na \rightarrow 2HO_2CCH(NH_2)(CH_2)_4SNa + 2CH_3I \rightarrow 2HO_2CCH(NH_2)(CH_2)_4SCH_3$$

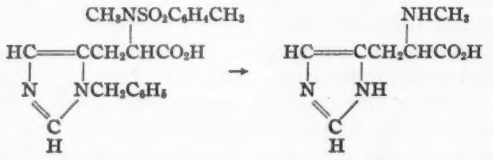
Similarly, *S*-benzylhexocystine was prepared in eighty-one per cent. yield by treating the reduction product of hexocystine with benzyl chloride in liquid ammonia.

$$[HO_2CCH(NH_2)(CH_2)_4]_2S_2 + 2Na \rightarrow 2HO_2CCH(NH_2)(CH_2)_4SNa + 2C_6H_5CH_2Cl \rightarrow 2HO_2CCH(NH_2)(CH_2)_4SCH_2C_6H_5$$

Du Vigneaud and Behrens (*94*) have described a method for the preparation of *l*-*N*-methylhistidine from *l*-histidine which precludes the possibility of the occurrence of a Walden inversion and racemization. Histidine was reduced by means of sodium in liquid ammonia at its boiling point and the resulting sodium salt treated with benzyl chloride to yield (fifty-seven per cent.) 1-(or 3)-benzyl-*l*-histidine.

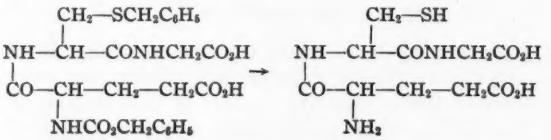


A small quantity of a dibenzyl derivative (eight per cent.) was isolated as a by-product of the reduction and subsequent benzylation. Having blocked the imino group of the imidazole ring by the introduction of a benzyl group, the *N*-benzyl compound was then converted to the *p*-toluenesulfonyl derivative, then methylated with methyl iodide. The resulting 1-(or 3)-benzyl-*N*-methyl-*N*-*p*-toluenesulfonyl-*l*-histidine was reduced by means of a solution of sodium in liquid ammonia, and from this reduction reaction, an eighty-eight per cent. yield of *l*-*N*-methylhistidine hydrochloride was isolated.

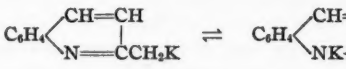


This procedure involves the simultaneous removal of the benzyl and *p*-toluenesulfonyl groups by reduction with sodium, and permits the preparation of a *N*-methyl derivative having the same spatial configuration as the parent compound. As pointed out by du Vigneaud and Behrens, it seems likely that reactions of this type will be found capable of extensive application.

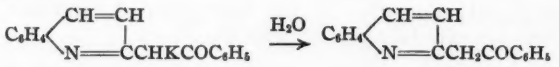
A seventy per cent. yield of an *O*-β-glucosidotyrosylgelatin (*95*) has been obtained by the reduction of *O*-β-glucosido-*N*-carbobenzyloxytyrosylgelatin with sodium and ammonium acetate in liquid ammonia. This method of reduction has the advantage of removing the carbobenzyloxy residues without rupturing the glucosido linkage and without degrading the protein molecule. A fifty per cent. yield of isoglutathione (α-glutamylcysteinylglycine) has been obtained by du Vigneaud and co-workers (*96*) by the action of sodium in liquid ammonia at −33.3° on *N*-carbobenzoxy-α-glutamyl-*S*-benzylcysteinylglycine,



In accordance with the view that quinaldine (2-methylquinoline) is a cyclic ketone ether of the ammonia system of compounds, this substance has been found to undergo a Claisen type condensation with certain esters of aromatic acids in the presence of from two to three equivalents of potassium amide (*97*). For example, potassium quinaldyl (prepared in liquid ammonia solution)



reacts with ethyl benzoate (in anhydrous ethyl ether) to form a salt which upon hydrolysis yields 2-phenacylquinoline.



This product is not reduced by an excess of sodium in liquid ammonia at −33° or 20°C.

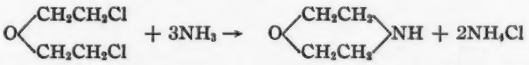
Roberts and Horvitz (*98*) have used liquid ammonia as a solvent and a dispersing agent in the preparation of various conjugate compounds of adrenaline with such substances as glycine, tyrosine, urea, glutamic acid, lactic acid, vitamin C, and cholesterol. The physiological activity of some of these ammonolyzed adrenaline conjugates was found to be much greater than ammonolyzed adrenaline.

Reference has been made to the application of the familiar liquid ammonia-sodium method to the determination of fluorine in organic fluorides (*99*). This method proved unsatisfactory in the analysis of carbon tetraiodide for iodine (*100*). A method for the rapid determination of moisture in liquid ammonia has been based on the precipitation of sodium hydroxide when sodium is titrated with ammonia at −35°C. (*101*). The tetrammonate of cupric nitrate is used as a catalyst

for this reaction and the determinations must be carried out in the absence of substances which catalyze the conversion of sodium to sodium amide. Known weights of sodium are titrated with measured quantities of ammonia and the percentage of water calculated from these data with an accuracy of 2–3 per cent. on samples containing as little as 0.01 per cent. H_2O. The method is also adaptable to the determination of total impurities in coal-tar ammonia, since sodium reacts with such impurities as phenols, pyridine, and unsaturated organic materials.

Attention has been called by Emeléus (*102*) to the analogies which may be drawn between liquid ammonia, sulfur dioxide, and water as ionizing and reaction media.

A patent has been granted on a process for the preparation of morpholine in eighty per cent. yield (*103*) by the interaction of *sym*-dichlorodiethyl ether and liquid ammonia in the presence of benzene. The reactions were carried out in an autoclave at 50°C. and over a period of twenty-four hours.



A process for the conversion of diaryl thioureas to the corresponding diaryl guanidines (*104*) has also been patented. These reactions were carried out in the presence of PbO in an autoclave at temperatures not exceeding 25°C. Other recent patents involving the use of liquid ammonia relate to the preparation of ethylene derivatives by the ammonolysis of tetra- and pentachloroethanes (*105*); the preparation of sulfuric esters of aliphatic alcohols (*106*), alkali metal ureas (*107*), amides of aliphatic acids (*108*), and alkali and alkaline earth metal carbamates (*109*); the extraction of phenol (*110*); and the recovery of ethylenediamine (*111*) from its salts.

The utilization of liquid ammonia is involved in a process for the separation of HCN from gaseous mixtures (*112*) resulting from the production of calcium cyanamide. A method has been devised for the extraction of calcium and magnesium from dolomite in the form of the nitrates (*113*). In this process the nitrates are formed by treating dolomite with liquid ammonia solutions of ammonium nitrate. A patent has been issued (*114*) involving the extraction of ergot from the crude product by means of liquid ammonia. The ergot is stabilized by converting it to the tartrate by means of tartaric acid. Another recent patent claims the use of liquid ammonia as a solvent for the extraction of sodium hydride (*115*) from a mixture of the hydride and sodium amide. It is of interest, in this connection, to note that Ruff and Geisel (*116*) have shown that the alkali metal hydrides are unstable in liquid ammonia since they react to form alkali amide and hydrogen,

$$NaH + NH_3 \rightarrow NaNH_2 + H_2$$

With sodium hydride, the reaction was found to proceed slowly at −40° and rapidly at 20°C.

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The HOME LAB *as a* HOBBY

MYRON A. COLER

Paragon Paint and Varnish Corporation, Long Island City, New York

HOME labs may range from space appropriated at the kitchen stove and sink to bare living quarters built around a relatively elegant laboratory. As is quite proper, the purpose of such a "chem" lab is usually to provide facilities to carry out some work in chemistry; however, the means may prove more valuable than the end. Thus, when the author succumbed to the bites of the "lab bug" at the impressionable age of about sixteen he thought that it would be nice to build a table and sink of his own to carry out some experiments. Then it seemed that it might be a good idea to add a couple of drawers, a few switches, and so forth. Good ideas of this type kept coming so that the actual construction work lagged while more elaborate plans were being formulated. By the time the lab was completed the author was pretty well entrenched in research work in the excellent laboratories of Columbia University; planning and making the lab had been so much fun and the spirit of "finishing the job" had been so dominant that the vanishing of the original need for the lab had hardly been noticed. Upon becoming aware of this situation, the author felt as if it were a veritable Frankenstein; the monster had consumed five years of spare time and then appeared to have no other immediate purpose than that of occupying space. This pessimistic reaction soon wore off and in the

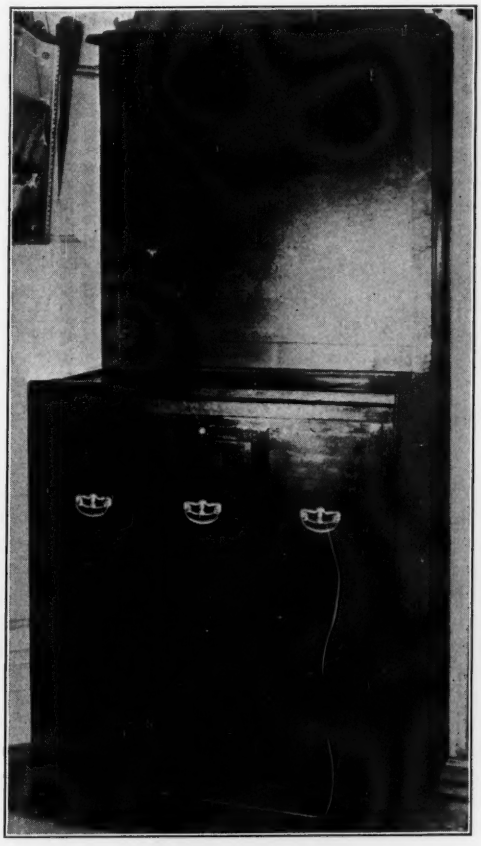


FIGURE 1
LAB CLOSED

FIGURE 2
LAB WITH FRONT PANEL REMOVED

ensuing years those hours spent in making the lab have proved to be a source of pleasant memories and valuable information. The author realizes that he has been "riding" a very profitable hobby and that it is possible to learn a good deal about chemistry and chemical engineering from just building a home lab in much the same way as "riding" the hobby of model ship building can-

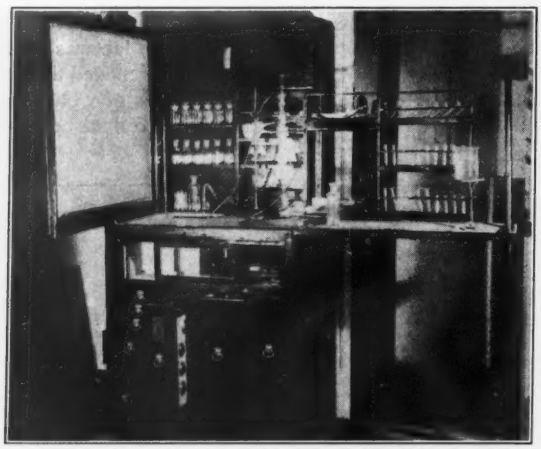


FIGURE 3
LAB COMPLETELY OPEN

not fail to improve the enthusiast's knowledge of navigation.

Like most hobbies, the building of a home lab involves the elements of collecting and arranging. The game is really one of collecting working facilities and, as is usually the case, the general collector, the one who wants to have built-in facilities for carrying out specialized work in electrochemistry, food chemistry, metallurgy, etc., has set himself an almost impossible problem to begin with. Of course, quite apart from interests, the financial resources of the enthusiast play a large part in determining just how much of a specialist he can afford to be. The less opulent must substitute ingenuity for prosperity; a surprising insight into the economics of engineering materials is acquired in worrying about the relative costs of soapstone, transite, lumber, pressed-wood, sheet metal, and so forth.

Compared with most "hobby-hounds," the home lab-builder has a particularly stiff problem in "arranging his collection" for, in addition to the desirable objectives of securing neatness, accessibility, and, if possible, a certain aesthetic charm, he is confronted with certain necessary objectives set by the regular safety requirements and his ability to anticipate likely sources of future trouble. The chagrin of a stamp collector who finds that all of the hinges in one of his albums have peeled is insignificant compared with that of a lab builder who discovers a major leak in a pipe line which he has so cleverly hidden that it is necessary to remove half of the shelving to make repairs. Sometimes the spacial restrictions may dominate the arrangement problem; if a lab is to be stored in a relatively small space when it is not in use it

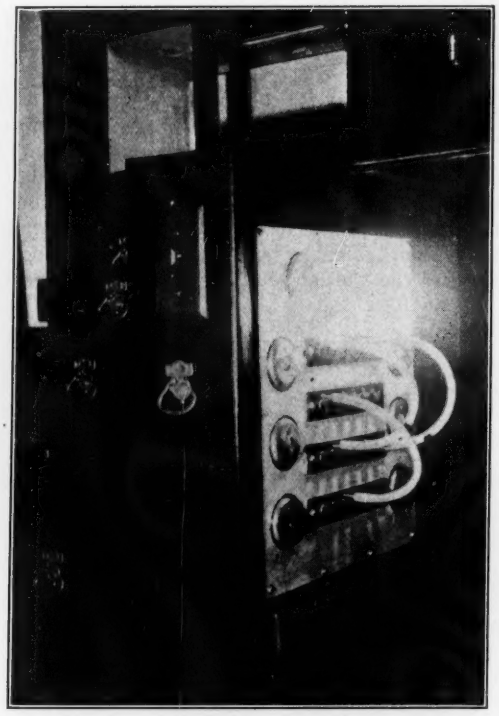


FIGURE 4
CLOSE-UP OF SWITCHBOARD AND HOOD

must be sufficiently light to be readily movable and sufficiently compact to provide the necessary facilities when "opened." The author's lab which is illustrated in the accompanying figures was designed to meet such restrictions.

In common with all worthy hobbies, the building of a home lab leads to an appreciation of many things which are otherwise taken for granted. The baffle-back of a hood, the form of an ordinary tripod, the concentric rings on a water bath are examples of homely items which proclaim in a quiet way the ingenuity of their inventors and the skill of their fabricators.

ACKNOWLEDGMENTS

The author is grateful to Mr. A. A. Cain for his kind, constant, and helpful interest in the problem of constructing a home lab and to Mr. William J. Withrow for the excellent photographs used in this article. Thanks are due the authorities of the Ethical Culture Schools of New York City who generously provided the working facilities for building the lab.

PROGRAM FOR THE MEETING OF THE DIVISION OF CHEMICAL EDUCATION OF THE AMERICAN CHEMICAL SOCIETY AT DALLAS, TEXAS, APRIL 18–21, 1938

There will be two special features on the program at the Dallas meeting: a symposium on the Teaching of Elementary Organic Chemistry and a student program. The latter will consist of a number of papers and contributions by present students of chemistry and talks by well-known chemists on subjects of active student interest. Special efforts are being made to obtain a large student attendance at the meeting, and the coöperation of all members of the Division is urged in this direction.

N. W. RAKESTRAW, *Secretary*

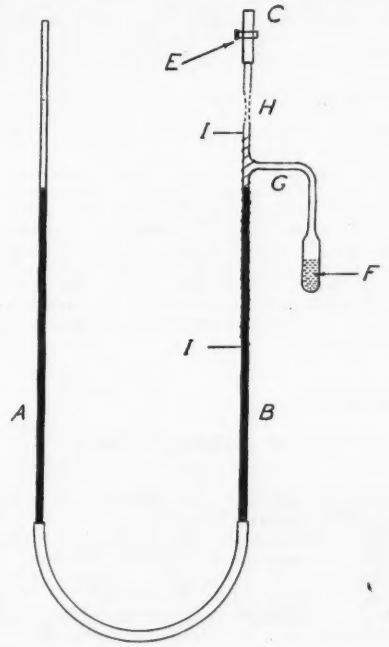
AN APPARATUS FOR DEMONSTRATING VAPOR PRESSURE

WARREN R. SMITH AND GEORGE H. RIDGELY

Lewis Institute, Chicago, Illinois

THE relations between vapor tension, vapor pressure, and boiling points are stumbling blocks for many students. To demonstrate these relations we have devised the apparatus shown. Its construction is not beyond the skill of the amateur glassblower.

A and *B* are ordinary glass tubing partly filled with mercury. *B* has a sidearm *G* carrying the bulb *F*. *D* is heavy-walled rubber tubing long enough to allow the adjustment of levels of the mercury in *A* and *B*. *C* is rubber tubing carrying a pinchcock *E*. The bulb *F* is partly filled with some liquid. (We have found ether convenient.) With the cock *E* open, *A* is raised until the mercury in *B* is level with the bottom of *G*. The liquid in *F* is boiled until all air has been driven out through *C*. While the liquid is still boiling the cock *E* is closed. *A* is lowered and *B* sealed at *H*. *I* is resistance wire wound around *B* and kept warm enough to prevent condensation of liquid. The temperature of *F* is controlled by dipping it in a beaker of water carrying a thermometer.



This apparatus gives results sufficiently accurate for ordinary classroom and laboratory demonstration.

THE METAL CARBONYLS. IV. PROPERTIES—A CORRECTION

Equation 1 on page 579 of this article [J. CHEM. EDUC., **14**, 575–81] should read

$$1.\quad Ni(CO)_4 + h\nu \rightarrow Ni(CO)_3 + CO$$

On page 580 the first equation should read

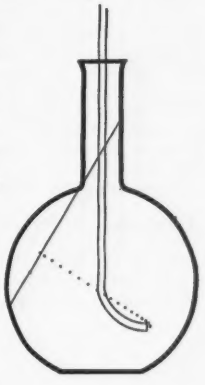
$$Fe(CO)_5 + h\nu \rightarrow Fe(CO)_4 + CO$$

A CONVENIENT GAS ABSORBER

PHILIP S. CHEN

Nashville Agricultural Normal Institute, Madison College, Tennessee

A convenient gas absorber for making saturated solutions of sulfur dioxide, hydrogen sulfide, chlorine, etc., can be made from any ordinary Florence or volumetric flask as illustrated in the figure. The flask is filled with the solvent liquid to the neck and then tilted until the level of the liquid fills the lower part of the neck so that the air space in the flask is sealed. Gas is now allowed to pass through the solvent by means of a glass tubing slightly bent at the lower end. Some of the advantages of this gas absorber are as follows.



1. The solvent liquid in the neck of the flask serves as a valve or check to prevent the gas from escaping.
2. The gas above the surface of the liquid is exposed to a larger surface than if the flask were not tilted, resulting in the larger amount of gas absorbed per unit time.
3. The absorption of the gas is further enhanced by the pressure created by the gas itself in the confined space above the liquid.

William O. Brooks
A. T. Burtsell
R. K. Carleton
Tenney L. Davis
C. K. Deischer
J. Howard Graham
B. Clifford Hendricks

ABSTRACTS

J. W. Howard
D. C. Lichtenwalner
Greta Oppe

C. M. Pruitt
Leopold Scheflan
A. A. Vernon
E. D. Walter
Mary Elvira Weeks
Sidney Weinhouse
G. H. Woollett

KEEPING UP WITH CHEMISTRY

Nickel alloys. R. J. McKay. *Chem. Industries*, **41**, 131–6 (Aug., 1937).—Research over the past several years has established that nickel alloys are resistant to the corrosive action of more than three hundred fifty products used in the chemical industries. It has also been found that nickel protects the purity of hundreds of chemicals in course of manufacture. It follows that manufacturers of chemicals should know how, why, and where nickel is of importance to their business. This importance arises from the fact that nickel alloys not only combine mechanical properties superior to mild steel but are highly resistant to corrosion. They also possess favorable working qualities.

Four principal varieties of nickel alloys find application in the chemical industries.

(1) Low alloys containing up to five per cent. nickel. Offered in steels, cast irons, and bronzes, they provide strength and toughness and improve the corrosion-resistant quality indirectly.

(2) Intermediate alloys containing from five per cent. to twenty-five per cent. nickel. Provided in nickel silvers, cast irons, and stainless steels, these alloys add directly to the corrosion-resistant quality of the material and provide beauty of appearance, strength, and toughness.

(3) High alloys, containing twenty-five per cent. to ninety per cent. nickel. These are highly resistant to corrosion and impart strength and toughness, combined with beauty. In this classification fall monel, a natural alloy of nickel and copper, and inconel, a nickel-chromium combination.

(4) Pure nickel, containing more than ninety-nine per cent. nickel, is produced in the various commercial shapes. This malleable nickel is used for cladding steel and other metals and pure nickel coatings can be produced by electro deposition in thicknesses which gave complete protection to the underlying material. In these forms it is malleable and ductile, strong and tough, and will take a high finish. A. T. B.

Deflocculation and controlled separation improve domestic china clay. F. E. Smith. *Chem. & Met. Eng.*, **44**, 594–6 (Oct., 1937).—Employing a continuous process embodying the deflocculation of finely ground clay from the non-clay substances has made it possible to produce from North Carolina clays a refined kaolin which is able to compete successfully with English china clay, even for the most exacting uses.

A flow sheet and further description of the plant is given. J. W. H.

Fiberglass. Anon. *Ind. Bull. of Arthur D. Little, Inc.*, **130**, 1 (Nov., 1937).—In October the Owens-Illinois Glass Company dedicated a research laboratory for manufacturing and using glass in fiber form, marking a definite beginning of a new chapter in the age-old art of glass-making. Heretofore most synthetic fibers have been formed of cellulose, the structural material of plant life; but this latest addition to man-made fibers starts with sand, recalling the words of the poet, Dante, "All can be spun, even the sands of the sea." The origin of all Fiberglass lies in one or the other of two basic operations—staple and continuous. "Staple" is an accumulation of comparatively short fibers, while "Continuous" is made up of seemingly endless filaments. Either form is turned into yarn and thread from which tape, cloth, and other textiles are fabricated. Fiberglass has proved itself practical for several kinds of electrical insulation, and wire covering, for chemical filtration, and for interior decorations. G. O.

Vanishing in thin air. Anon. *Ind. Bull. of Arthur D. Little, Inc.*, **130**, 4 (Nov., 1937).—Molecular stills and improved high-vacuum pumps are soon to be marketed by the Eastman Kodak Company. Molecular distillation makes possible the distillation of fatty oils whose decomposition temperatures are below their boiling points and commercial production of vitamin concentrates. The rapidly expanding list of inventions depending for industrial success upon high vacua broadens the significance of these developments. Langmuir developed the mercury condensation pump over twenty years ago, but even the low vapor pressure of mercury is too high for use in creating really high vacua. G. O.

Phosphorus for progress. S. D. Kirkpatrick. *Chem. & Met. Eng.*, **44**, 644–50 (Nov., 1937).—The Monsanto Chemical Company has successfully developed the large scale production and utilization of elemental phosphorus in such a way as to open up an entirely new field in chemical industry. They have made phosphorus available in tank car lots. This means that new organic and inorganic compounds of this valuable element will be made. In fifteen months a comprehensive program of research and development has been translated into successful production.

As mined the phosphate matrix consists of two grades: a low and a high. The high grade is crushed and goes directly to the sintering machine. The clay in the low grade must first be removed in a washing machine.

The crushed matrix is moistened, mixed with finely ground coke and fed into the sintering machine. The sintered product is cooled, ground, sized, and conveyed to the electric furnace. The phosphorus vapors from the furnace are condensed, run into pumps, and pumped with water into huge storage tanks. From these tanks the phosphorus is pumped into tank cars.

The molten slag is quenched in water. The heavier ferrophosphorus in which form the iron leaves the furnace is cast into moulds and sold to the steel industry for regulating the phosphorus content of steel. J. W. H.

SCIENTIFIC REVIEWS AND BIBLIOGRAPHIES; TABULATIONS OF SCIENTIFIC DATA

Low temperature research—I. The production and measurement of low temperatures. D. J. Williams. *Sch. Sci. Rev.*, **19**, 33–43 (Oct., 1937).—This article describes the crowning achievements of work lasting over a century, and a list of important dates makes a useful introduction.

The Approach to Absolute Zero

1755. First ice-making machine (Cullen).
1790. Ammonia liquefied (Van Marum and Troostwyk).
1823. Chlorine liquefied (Faraday).
1824. Bussy demonstrated liquefaction by cooling only.
1834. First compression refrigerating machine (Perkins).
1845. First cold air refrigerating machine (Gorrie).
1853. Joule Thompson effect discovered.
1858. First compression refrigerating machine (Harrison).
1863. Andrew's work on critical state published.

1868. Helium discovered in the sun (Janssen).
1876. First ammonia compression refrigerating machine (Linde).
1883. Oxygen and nitrogen liquefied (Wroblewski and Olszewski).
1891. Dewar flask invented.
1894. Argon discovered (Rayleigh and Ramsay).
1895. Air liquefied by Joule Thompson effect (Linde and Hampson).
1898. Dewar published account of the liquefaction of a small quantity of hydrogen.
1902. Claude expansion engine.
1903. First industrial oxygen plant (Linde).
1908. Helium liquefied (Kammerlingh Onnes).
1911. Superconductivity discovered (Kammerlingh Onnes).
1924. Commercial production of solid carbon dioxide.
1926. Helium solidified (Keesom).
Debye and Giauque suggested adiabatic demagnetization.
1933. Giauque and McDougall by adiabatic demagnetization of gadolinium sulfate reached 0.25°K.
Using cerium fluoride, deHaas, Kramers, and Wiersma, reached 0.27°K.; using cerium ethyl sulfate they reached 0.085°K., and again using potassium chrome alum 0.05°K.
1935. February 5. deHaas cabled the news that he had reached 0.005°K.

In this article is described the liquefaction and magnetic methods for the production of low temperatures, and the methods of low-temperature measurement. S. W.

The composition of bleaching powder. G. FOWLES. *Sch. Sci. Rev.*, **19**, 23–32 (Oct., 1937).—Of all the compounds manufactured directly from chlorine, the one produced in the greatest abundance is the familiar chloride of lime, or bleaching powder. Its cheapness, its efficiency as a bleaching agent, and its great germicidal power has made its use world-wide. Ever since C. Tennant began the manufacture of bleaching powder in 1799, generations of chemists have toiled at the problem of elucidating its composition and the mechanisms of its reactions with the hope of increasing its stability and improving its methods of manufacture. It was not until 1935 that a trio of English chemists, Bunn, Clark, and Clifford, brought forward incontestable proof, through X-ray spectra, that the chief constituents of bleaching powder are basic calcium chloride and basic calcium hypochlorite, $CaCl_2Ca(OH)_2H_2O$, and $Ca(OCl)_2{\cdot}2Ca(OH)_2$. The article contains the history of the chemistry of bleaching powder, and includes five references. S. W.

Scientific progress in the field of chemical insecticides. L. SPRENGEL. *Angew. Chem.*, **50**, 560–9 (July 10, 1937).—A survey is given which deals with toxicological methods of testing insecticides, testing the effectiveness of poisonous property of insecticides, determination of physiological properties and substitution products. Many references are cited. L. S.

Electrical discharges as an aid in chemical synthesis. P. W. SCHENK. *Angew. Chem.*, **50**, 535–46 (July 10, 1937).—A survey covering the chemical effect of discharges at high pressure, active modifications, cleavage reactions, reactions between several gases, electrical discharge at low pressures, mechanism of reactions during discharge, chemical effect of glow discharge, formation of atoms during discharge, reactions with atoms, syntheses during glow discharge, reactions with oxygen, reductions, various syntheses, experiments on the preparation of noble gas compounds. Electrical discharges have proved to be a valuable assistant in the field of preparative chemistry; however, their industrial application has not yet been developed. One hundred forty-seven references. L. S.

Our knowledge of the structure and composition of the earth crust. P. DORN. *Chem.-Ztg.*, **61**, 713–5 (Sept. 4, 1937).—Tables are quoted from various reports giving the frequency in percentage of various elements in the earth crust, the chemical composition of the outer portion of the earth crust, the chemical composition of the earth, the chemical composition of the surface of North and South America, Europe, Asia, Africa, Australia, the Antarctic, the Atlantic and Pacific regions, and the contents of rock-forming minerals in the structure of the uppermost portion of the earth crust. Three-fourths of the granite layer of the earth crust consists of a mixture of silicates of aluminum, calcium, magnesium, sodium, potassium, and iron. Eighteen references. L. S.

Caoutchouc as a chemical raw material. A. NIELSON. *Chem.-Ztg.*, **61**, 721–3 (Sept. 8, 1937).—A survey. Thirty-five references. L. S.

Nickel as a catalyst. O. B. J. FRASER. *Trans. Electrochem. Soc.*, **71**, 425 (1937).—The literature, both patent and general, on the use of nickel as a catalyst has been largely digested and summarized. Fields touched upon in the paper are, in order of presentation, oil and fat hardening, hydrogen and the oxides of carbon, hydrogenation of hydrocarbons, miscellaneous organic hydrogenations, hydrocarbon purification by hydrogenation, removal of sulfur from hydrocarbon oils by hydrogenation, artificial aging of distilled liquors, inorganic hydrogenations, dehydrogenation and polymerization of organic compounds, simultaneous hydrogenation and dehydrogenation, decomposition of carbon monoxide, carbon oxides, and hydrocarbons, carbon monoxide and ammonia, carbon monoxide and steam, hydrogen from hydrocarbon gases, condensation, isomerization, esterification, hydration and dehydration, addition and elimination of halogens, oxidation of carbon, carbon monoxide, and organic compounds, drying oils, oxidation of oils and fats, hydrogen and oxygen, oxidation of sulfides, miscellaneous reactions of sulfides, oxidation of sulfur dioxide, ammonia oxidation, oxidation of atmospheric nitrogen, bleaching, waste water purification, absorption, negative catalysis and inhibitors, miscellaneous organic reactions, miscellaneous inorganic reactions, and electrochemical processes.

Preceding the fields covered in the foregoing paragraph are a brief historical foreword and a discussion of the types of nickel materials and amounts consumed for catalyst material in North America and in parts of Europe. The paper is concluded with a general discussion of the properties of nickel and nickel compounds that have catalytic interest.

Reactions at high pressures and the apparatus employed. B. WAESER. *Chem.-Ztg.*, **61**, 534–5 (June 30, 1937).—A review of the literature. Thirty-eight references. L. S.

The yellow ferment (flavin enzyme). F. WEYGAND. *Chem.-Ztg.*, **61**, 545–9 (July 3, 1937).—A review dealing with historical events, occurrence and preparation, properties, reactive group, carriers, synthetic ferments, Warburg's system, and physiological importance. Forty-seven references. L. S.

75 years of calcium carbide; in memory of Friedrich Wöhler's discovery of 1862. F. A. HENGLEIN. *Chem.-Ztg.*, **61**, 684–5 (Aug. 21, 1937).—A historical review. L. S.

The industrial utilization of molasses in the U. S. A. C. PIETRUSKY. *Chem.-Ztg.*, **61**, 557–9 (July 7, 1937).—A review of the manufacture of alcohol, mannitol and sorbitol, citric, lactic, formic, butyric, oxalic, and gluconic acids, and glycerine from molasses. L. S.

EDUCATIONAL MEASUREMENTS AND DATA

Making tomorrow's chemical engineers. A. E. MARSHALL. *Chem. & Met. Eng.*, **44**, 682 (Nov., 1937).—It is the opinion of this author that some large part of the engineering students should be drawn from special technical high schools where the two years prior to university entrance would be principally devoted to English, mathematics, economic history, chemistry, physics, mechanical drawing, shop, and a foreign language, preferably German. As this seems an ideal which is a long way off a practical intermediate step would be a five-year course for the degree of Bachelor of Science in Engineering, with curricula so devised that men could graduate in four years with a Bachelor of Arts degree if circumstances made the fifth year impossible. Some participation in organized industrial effort, preferably beginning in the summer before entrance and in some of the succeeding university years would quicken interest in the study of psychology, sociology, and even economics by making them real instead of abstract subjects.

It is unfair to permit youth to be a schoolboy until a degree is secured and then suddenly to demand an ability to understand men and be welcomed as a man among men. J. W. H.

RECENT BOOKS

SELECTED TOPICS IN COLLOID CHEMISTRY WITH ESPECIAL REFERENCE TO BIOCHEMICAL PROBLEMS. *Ross Aiken Gortner*, Professor of Agricultural Biochemistry in the University of Minnesota. Cornell University Press, Ithaca, New York, 1937. xiii + 169 pp. 35 figs. 15 × 23 cm. $2.50.

This stimulating book contains material presented at Cornell University when Professor Ross Aiken Gortner held the George Fisher Baker Non-Resident Lectureship in Chemistry. He incorporated in these studies of colloidal material a discussion of the investigations conducted in his own laboratories.

"Biochemists and biophysicists will find here important extensions of their subjects. Since protoplasm is a colloidal system, and the reactions of life take place in a colloidal medium, the student of living processes must familiarize himself with the basic physico-chemical principles underlying colloidal phenomena."

The author's historical appreciation of the work of the great pioneer, Thomas Graham, is excellent, and his selections from Graham's writings are unusually illuminating. In discussing the peptization of the protein of wheat and other grains by solutions of various salts, Dr. Gortner speaks with the authority of extended experience. The section on ultrafiltration is particularly good, calling attention as it does to the importance of electrical effects and of surface tension as modifying the influence of pore size and particle size.

The hydration of starches and the viscosity effects of changes in this hydration are well brought out. As might be expected from Dr. Gortner's laboratory, a clear discussion of electrokinetics of colloidal systems is offered. One could wish that on page 76 Dr. Gortner had the courage to break away from the hackneyed phrase "electroendosmosis" and to use instead "electricosmose" which includes movement of a liquid through a gel or capillary in either direction. The distinction between electrokinetic or zeta potential and thermodynamic potential is well made. On page 81 there is a helpful description of a streaming potential cell to be used in emulsion studies.

Under surface tension there is much material on molecular orientation and on monomolecular films, as well as the built-up polymolecular layers recently studied by Langmuir. Adsorption might have received a little more emphasis, considering its great importance, yet it is difficult to find any cause for criticism of this helpful book. Occasionally the author startles the reader with such arresting facts as the following one cited on page 126. Dried seeds, which probably have at the most an osmotic pressure of 175 atmospheres, will swell, taking up eight or nine per cent. of water when in a saturated aqueous solution of lithium chloride. Since the osmotic pressure of the lithium chloride solution is about 1000 atmospheres, obviously this is a colloidal binding of water, rather than an osmotic pressure phenomenon.

The author has certainly succeeded in his plan to stimulate teacher and pupil by opening the doors to fascinating vistas of colloidal theories and applications.

HARRY N. HOLMES

OBERLIN COLLEGE
OBERLIN, OHIO

MAN'S PHYSICAL UNIVERSE. A. T. Bawden, College of the Pacific, The Stockton Junior College. The Macmillan Co., New York City, 1937. xvii + 812 pp. 368 figs. 14 × 21 cm. $3.50.

The author has made his position clear in the preface. In his own words the book "is intended to be used as a text for survey courses in physical science." It is to be used in connection with a course "designed to bring from the archives of physical sicence the most important facts and generalizations which have any bearing on these aspects ['problems of life today'] of man's experience." The author is greatly concerned "that the student be led to develop open critical and cultural attitudes of mind, that will lead him to attempt to use the scientific method in solving all the problems of life." At the same time he is of the opinion that "in such a work it is inevitable that the experimental basis for many of the ideas presented must be omitted." Above all he aims to present "a meaning of lasting value" which is "essentially socio-centric."

The book consists of ten divisions or "units." The first unit is essentially a general discussion of science and its importance in our industrial civilization, and of the scientific attitude and method. The last unit includes a reconsideration of the social consequences of scientific progress. Although the lengthy titles (intended to express the important generalization of the unit) fail to reveal the nature of subject matter, the following translation would be a fair indication of the content, in the sequence presented: astronomy, geology, molecular physics and heat, energy, wave motion, magnetism and electricity, atomic structure and chemical change, applied chemistry. Thus the course consists essentially of four units of physics, two of chemistry, and one each of astronomy and geology.

It is difficult to disagree with the author either on his aims or on the apportionment of subject matter. Yet, perhaps the author would object to the analysis made above, for he has sought to teach not the various sciences, but *science*. Though he has been successful in integrating subject matter in some instances, on the whole he has fallen short of his own expectations. While he pays lip service to the scientific method, his discussion in the introductory unit is devious, and his use of it in the main body of the book is scanty. It is the firm belief of the reviewer that the scientific method can best be taught by repeated use. Perhaps the most successful approach would be to show logically how from the experimental evidence great generalizations of science have been developed, and how these lead directly to an understanding of a few selected and important phenomena of every experience as well as to the significant applications that shape the course of our civilization.

It is precisely this approach that the author has avoided. In the attempt to make the course "socialized," the author has gathered in each section much heterogeneous material—largely factual, but also some laws and principles. On the whole, the material is undigested, and consequently unorganized, disconnected, and confusing. Nor is the information always authoritative. Not uncommon are statements of the type, "The molecules of gases are about as far apart from each other in relation to their size as the stars are in relation to their size." There is a lack of intellectuality, so that one finds section titles such as "The whole electromagnetic spectrum is of extreme interest today" and study questions of the type, "What is the goal of humanity?" and "Analyse your attitude toward 'cheating.'" The treatment of Einstein is immature and pointless. It is probably not unfair to characterize the work as an overgrown ninth-grade general science text.

THEODORE A. ASHFORD

UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

LABORATORY AND WORKBOOK UNITS IN CHEMISTRY. *Maurice U. Ames*, George Washington High School, New York City, and *Bernard Jaffe*, Bushwick High School, New York City. Nonconsumable Edition. Silver, Burdett Company, New York City, 1937. xiv + 255 pp. 13.5 × 19.7 cm. $1.12.

Of late years it has seemed the proper thing for an author of a chemistry text to bring out a "workbook" instead of a "laboratory manual." While this book comes under the first classification, it stresses the directions for the experiments and reduces to a workable minimum the teaching devices and other educational

mechanics which have been so overdone in some recent "workbooks."

The experiments covered are those usually found in similar laboratory manuals. The text is divided into forty-six experimental units, followed by five units on Review of Equations, Chemical Arithmetic, Biography, Table of Common Substances and Alloys, and Review of Important Terms and Laws. The appendix contains seven items of the usual referential nature.

This book tries to "integrate" . . . "demonstrations witnessed by the student, individual laboratory work, classroom work with the textbook, and reference work in the library." The preface says, "Each unit begins with experiments," and is followed by "Observations and Questions on the Experiments" and "Conclusions," but this order is not carried out consistently in all units. Some units include also "Supplementary Exercises" and "Optional Questions" for the more gifted students.

The preface also says, "The lists of apparatus and materials, customarily placed at the head of each experiment, are placed instead at the back of the book for convenient reference by the teacher, the laboratory assistant, or the student. The experiments have been so planned that they may be performed with simple apparatus and inexpensive materials in small amounts." Certain experiments are indicated as best suited for teacher demonstration.

Illustrations of set-ups of apparatus are all diagrams and not half-tones, are clear, show essential parts, omit non-essential parts, and are easily reproduced by the student. All glass tubes and thistle tubes are correctly shown with open ends, indicating coöperation between authors and draftsman.

Inconsistency in the use of units of measurement mars the scientific consistency of the text. These terms appear: inches, cubic centimeters, teaspoonsful, meters, and grams. This will doubtless be changed in the next edition. There is a marked freedom from typographical errors; the most glaring one is "Flourine" for "Fluorine" in the Table of Contents.

There are apparently only four quantitative experiments: per cent. of water of crystallization, weight of 22.4 liters of oxygen, equivalent weight of magnesium, and per cent. of oxygen in air. The tables for data and calculations are good. The directions themselves might have been more explicit, to the advantage of teachers who do not like to amplify the tests orally. If the beam balance shown under Units 3 and 8 is to be used, one might question the value of the first three of these experiments. As the magnesium ribbon used in the equivalent weight experiment must be weighed to the third decimal place, probably a case balance is to be used, but it is not mentioned, nor is its use described.

The unit on Chemical Arithmetic is unusually well done. There are a few minor criticisms. The last line on page 201 might be improved if it read "one gram molecular weight" instead of "one molecular weight"; the per cent. sign at the end of Example A on page 216 is plainly a typographical error. Is it mathematically and chemically correct to say that "17 grams = 22.4 liters" (see page 210) when one wishes to say that 17 grams of ammonia occupy 22.4 liters at S. T. P.?

It is unfortunate that the authors did not adopt the improved style of formula for hydrated salts, *e. g.*, $CuSO_4 \cdot (H_2O)_5$ instead of the older $CuSO_4 \cdot 5H_2O$, as recommended by the Committee on Labels of the Division of Chemical Education of the American Chemical Society.

In general, the text is well written, attractively set up, and should be a pleasure to use.

WILHELM SEGERBLOM

THE PHILLIPS EXETER ACADEMY
EXETER, NEW HAMPSHIRE

LABORATORY AND WORKBOOK UNITS IN CHEMISTRY. *Maurice U. Ames*, George Washington High School, New York City, and *Bernard Jaffe*, Bushwick High School, New York City. Consumable Edition. Silver, Burdett Company, New York City, 1937. xvii + 237 pp. 20.3 × 26 cm. $0.84.

The text material is practically the same in both the Consumable Edition and the Nonconsumable Edition, so the first review applies to this edition of the book.

In the Consumable Edition each leaf is punched and perforated so that records of the experiments can be removed to a loose-leaf cover, if it is desirable. Diagrams of all of the thirty-one apparatus set-ups needed for the course are included in pages xi to xvii inclusive, whereas in the Nonconsumable Edition each set-up diagram is included under the heading of the experiment in which it is to be used.

WILHELM SEGERBLOM

THE PHILLIPS EXETER ACADEMY
EXETER, NEW HAMPSHIRE

TYPICAL QUESTIONS AND PROBLEMS IN GENERAL CHEMISTRY. *G. N. Quam*, Associate Professor of Chemistry, Long Island University. Fifth edition. Edwards Brothers, Inc., Ann Arbor, Michigan, 1937. v + 105 pp. 21.5 × 29 cm. $1.75.

This book is a loose-leaf compilation, in a sturdy binder, of over eight hundred questions, problems, and exercises, many of which contain several parts. They are arranged in thirty-one groups, corresponding to chapter divisions almost universally used in general chemistry textbooks. The appendix contains useful data, and also a table of logarithms. Periodical references suitable for elementary students are frequently given, supplementing a comprehensive list of general references.

This book should be of material assistance in obtaining a high level of effort and understanding from students.

LOTHROP SMITH

THE STATE UNIVERSITY OF IOWA
IOWA CITY, IOWA

NEW WORLD OF CHEMISTRY. *Bernard Jaffe*, Chairman, Department of Physical Sciences, Bushwick High School, New York City. Silver, Burdett and Co., New York City, 1937. xii + 566 pp. Appendix and index, xxx pp. 339 figs. 14 × 20 cm. $1.80.

An excellent review of the first edition of this high-school chemistry text was written by Herbert R. Smith and appeared in the August, 1935, issue of THIS JOURNAL. In the preface to the 1937 edition, the author states, "The isolation of pure vitamin E, the discovery of artificial radioactivity, the wider use of glass for building and insulating purposes, the production of a new type of safety glass . . . . are some of the new developments now treated in this text.

"As the result of the rapid pace of chemical research, some of the fundamental theories of chemistry are still undergoing modification. The discussion of atomic structure in Chapter 11 and all the electronic diagrams throughout the book have, therefore, been modified in accordance with the latest accepted findings."

These changes in text involve only a restatement of a sentence or a paragraph at most. The definitions of neutralization and hydrolysis have been restated. Ionic equations throughout the book have been changed from

$$Na^+OH^- + H^+Cl^- \rightarrow Na^+Cl^- + HOH$$

to read

$$Na^+ + OH^- + H^+ + Cl^- \rightarrow Na^+ + Cl^- + HOH$$

Although the latter equation is in correct usage, the writer has found that it is much more confusing to the average high-school pupil because of the additional plus signs.

In the first edition several references are made to current articles in the JOURNAL OF CHEMICAL EDUCATION and other periodicals. No additional references have been made to articles appearing in issues of the past two years.

The writer wishes that the author might make the chapters on organic chemistry a more vital part of the book by placing them earlier in the text. Many teachers follow the text in chapter order, and many times the last chapters are only skimmed over or omitted entirely. If organic chemistry is not made too technical, its lessons and applications can be thoroughly discussed with the pupils and become a usable part of their chemical education.

The writer understands from one teacher who is using this

text that the historical approach and the recurring use of chemists' names throughout the treatment of a subject are interesting to the pupil. To illustrate: the author uses two pages to interest the pupil in Arrhenius and makes thirteen references to him in the following seven pages. Thereby the chemist is made real to the pupil, and the association is carried through the section dealing with the topic.

MARTIN V. MCGILL

LORAIN HIGH SCHOOL
LORAIN, OHIO

QUALITATIVE ANALYSIS. *H. V. Anderson*, B.Ch.E., M.S., Associate Professor of Chemistry, Lehigh University, and *T. H. Hazlehurst*, A.B., Ph.D., Assistant Professor of Chemistry, Lehigh University. Second Revised Edition. Prentice-Hall, Inc., New York City, 1937. xiii + 280 pp. 8 figs. 13.5 × 20.5 cm. $2.25.

The recent trend in the presentation of qualitative analysis has been to show the relation of modern theory, especially physical chemical, to the methods of analysis. The second revised edition of this book, with nearly a complete change in authors—first edition written by J. S. Long, D. S. Chamberlin, and H. V. Anderson—conforms with this idea. In the preface to this edition the authors say, "The principal objective has been to arrive at a more logical and clearer presentation of the principles underlying the science of chemistry and of the physical processes behind such commonplace phenomena as solution and crystallization." In accordance with this objective, the first half of the book is devoted to a discussion of theory with occasional reference to the laboratory work. Topics, important to qualitative analysis, dealing with ionization, mass action, common ion effect, solubility product, oxidation-reduction, and subdivisions thereof are presented in a readable fashion. Some new concepts such as the electronic structure of atoms and molecules and the new idea of acids and bases are included. At the end of the discussion of each topic, typical questions or problems appear which test the student's understanding of the subject matter.

Though it is often necessary to refresh the minds of students there seems to be duplication of some material usually found in a good modern text on general chemistry. It seems unusual that such important subjects as complex ions, salt effect, adsorption, and coprecipitation have not more space devoted to their discussion, and complete ionization of strong electrolytes is not mentioned. The idea presented in Chapter 2 that highly ionized substances are less than one hundred per cent. ionized, and on page 36, that there are some unionized silver chloride molecules in a saturated solution indicate an obsolete point of view. It would have been much more in keeping with the trend to modernization of the subject if most of the equations had not been written in molecular, but in ionic form.

The laboratory work is planned after the usually accepted procedure of first performing preliminary experiments on the various cations of a group. Then an analysis is carried out, employing a method which is indicated by the experiments. Explanatory notes appear after each group, together with a set of review questions.

As in other chemical fields, methods of analysis have made considerable progress in recent years. Notwithstanding the authors' statement in the preface, the laboratory methods could have been kept up to date. Certain procedures such as the use of ammonium polysulfide to separate groups 2A and 2B, the use of dilute hydrochloric acid to separate nickel and cobalt sulfide from the remainder of the ammonium sulfide group, the failure to mention the usual presence of magnesium in group 4, the use of perchloric acid to detect potassium, and the reliance on a flame test for the detection of sodium could have been considerably improved upon. Apparently one great fault with most recent texts on qualitative analysis is that they modernize the theory and lose sight of the fact that it is a laboratory science. The analysis of anions is quite well planned and takes in a number of acids usually not considered in an elementary course. For some of the acids, however, there are much better identifying tests than those which are given. Under the analyses of solutions and solids, the possibility of interferences of acids in the detection of metal ions is not considered.

The book is well printed and is quite free of typographical errors.

LEO LEHRMAN

THE COLLEGE OF THE CITY OF NEW YORK
NEW YORK CITY

THE GOLDSMITH'S HANDBOOK. *George E. Gee.* Chemical Publishing Co., of New York, Inc., New York City, 1937. xxiv + 263 pp. 12.5 × 18.5 cm. $2.50.

This book, with its absence of technical and scientific terms, written expressly for the worker in gold, will be found quite readable by those who lack chemical training.

Frequent tables which fix arbitrarily the proper mixtures and conditions for the production of jeweler's alloys and their fabrication will be useful primarily to the artificer.

As a contribution to chemical education the value of the book is small.

CROSBY F. BAKER

TUFTS COLLEGE
TUFTS COLLEGE, MASSACHUSETTS

THE FINE STRUCTURE OF MATTER. Part I. X-Rays and the Structure of Matter. *C. H. Douglas Clark*, Assistant Lecturer in Inorganic Chemistry in the University of Leeds. John Wiley & Sons, Inc., New York City, 1937. lxxii + 216 pp. 14 × 22 cm. $4.25.

This book forms Part I, Volume II of A COMPREHENSIVE TREATISE OF ATOMIC AND MOLECULAR STRUCTURE. In the opinion of the reviewer, the book must be considered as a classified bibliography of crystal structure, and not as a comprehensive treatise of the subject. Only the last chapter represents a discussion of the more general results of crystal structure work.

Apart from this last chapter (and the introductory chapter I) the book represents a compilation of the compounds which have been examined by X-rays (up to 1936). These compounds are divided into three main groups, inorganic, organic, and metallic. For every substance are listed the cell dimensions, the number of molecules per cell and the space group. However, the author does not indicate which structures have been completely determined. Clearly, this information would have been of importance, as in general the determination only of cell size and space group is of little value.

In the text the author describes the more common types of structures, and there are brief remarks about a few additional structures. These remarks are uncritical; hence they are often irrelevant and sometimes outright incorrect.

In Chapter IX the author mentions briefly a few of the fundamental results of V. M. Goldschmidt, but also this chapter is written with the same lack of authority that characterizes the entire book. The appendix on "Atomic Structure Factors" is confused, as well as confusing. The author obviously does not know the difference between the atomic structure factor (atomic scattering power) and crystal structure factor. Thus on page 211 the symbol F, according to definition, represents atomic structure factor. A few lines below, however, the same symbol, without further notice, represents the crystal structure factor. The statement on the same page that "for even orders of reflections from ionic crystals, the structure factors of the ions are added, and for odd orders subtracted," is incorrect, even if we choose the proper alternative of the ambiguous term structure factor. The statement is only true for crystals of the sodium chloride type of structure (whether they are ionic or not).

The reviewer is willing to admit that the book can be used as a classified bibliography. The text, however, is so full of incorrect statements and ambiguities that the book cannot be recommended.

W. H. ZACHARIASEN

UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

THE APPLICATION OF CHEMISTRY TO AGRICULTURE

By

C. C. HEDGES and H. R. BRAYTON
of the Agricultural and Mechanical College of Texas

THIS clear, practical and concise presentation of the principal topics of the chemistry of agriculture is intended to show the relationship between water, seeds, and their germination, plants, the atmosphere, soils, fertilizers, insecticides, and fungicides. It includes a summary of the general principles of organic chemistry and an adequate discussion of animal nutrition.

It differs from other texts in its field in that it confines itself to fundamentals and is designed to give a coördinated view of chemistry in its application to agriculture. Other texts in the same field are either too encyclopedic for effective instructional use or too limited in scope and too advanced in treatment.

LABORATORY MANUAL

Laboratory Manual of Agricultural Chemistry, by C. C. Hedges and H. R. Brayton, has been revised and brought up to date to accompany the same authors' new text. The purpose of the 63 experiments in this manual is to teach the student the significance of different kinds of analysis rather than to provide laboratory training for analytical chemists.

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By Charles W. Stillwell, Research Division, Dennison Manufacturing Company, Framingham, Mass. *International Chemical Series.* 431 pages, $4.50

Gives the student a simple yet accurate account of the basic principles of crystal chemistry—the study of the laws governing the arrangement of ions, atoms, or molecules in solids, of the nature of the forces binding them together, and of the influence of arrangement and binding forces upon the chemical and physical properties of the solids. While not exhaustive in detail, this is the only relatively complete approach to the subject in book form, in so far as general conceptions are concerned.

Arthur and Smith's
SEMI-MICRO QUALITATIVE ANALYSIS

By Paul Arthur and O. M. Smith, Oklahoma A. & M. College. *International Chemical Series.* 198 pages, $2.00

Presents a system of semi-micro qualitative analysis that is clear, understandable, and, as far as possible, self-administrating. The instructions have been made as simple as possible and care has been used to keep that balance between theory and technique that is needed by the average student in elementary qualitative analysis.

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Endeavors to give the student a background of essential facts that will enable him to proceed with the study of the subject in the current literature. The book is divided into three parts: (1) discussion of the facts of biochemistry; (2) laboratory experiments; (3) special experiments which may be assigned to groups of two or more students.

Jordan and DeKay
QUALITATIVE ANALYSIS FOR STUDENTS OF PHARMACY AND MEDICINE

New second edition

By C. B. Jordan and H. G. DeKay, Purdue University. *McGraw-Hill Publications in Pharmacy.* In press. Ready in March.

In revising this well-known text designed expressly for students in schools of pharmacy the authors have brought all material completely up to date. The official preparations of the U. S. Pharmacopoeia and National Formulary VI are included; problems and explanations of problems on ionization, common ion effect, solubility product, etc., have been added, and a discussion of the hydrogen ion concentration (pH) has been included.

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McGRAW-HILL BOOK COMPANY, Inc.

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TRADE ANNOUNCEMENTS

New Binder for JOURNAL OF CHEMICAL EDUCATION

A new binder for the JOURNAL OF CHEMICAL EDUCATION has been recently announced by the *Modern Binder Corporation, Weehawken, New Jersey.* The binder is covered with black fabrikoid which simulates leather. The metal devices which hold the magazines in place are of cadmium plated steel. Copies may be bound without punching, cutting, or marring the magazines in any way. The Modern Binder Corporation also manufactures binders for other scientific publications.

New Source of Ultra-Violet Has Improved Efficiency

A new, highly flexible source of ultra-violet radiation, consisting of a quartz-tube mercury vapor arc of improved efficiency mounted within a special reflector on a portable laboratory stand, has just been announced by the *General Electric Vapor Lamp Company, Hoboken, New Jersey.* The unit is operated from any 120-volt or 220-volt A.C. line, through a portable auto-transformer supplied as part of the complete assembly. The sealed mercury vapor tube has high radiation characteristics in both the near and far ultra-violet zones, without the high heat losses and operating and maintenance problems inherent in open arcs. Rated operating life of the new tube is two thousand hours.

In contrast to previous models, the new Type H Uviarc is self-starting, requiring no tilting nor use of auxiliary moving parts.

In the laboratory, the adjustable mount for the tube and reflector assembly make it easy to direct the radiation to the desired location, or to change the intensity by raising or lowering the source. If desired, the unit can easily be built-in as a part of permanent equipment for industrial radiation. For test work requiring portability, the auto-transformer comes equipped with a removable handle, and the supporting stand for the reflector fits in place in a special bracket on the end of the transformer, to form a compact self-supporting unit.

RADIATION OUTPUT OF TYPE H UVIARC

Arc Tube i.d. (in.)	5/8
Arc Length (in.)	6.0
Volts	150.0
Amps	3.0
Arc Watts	360.0
Lumens	12,600.0
Lumens per Watt	35.0
Total Watts	410.0

Wave length (A.U.) Lines and Bands	Spectral Intensities (Microwatts per cm.² at one meter distance from lamp axis) developed by the lamp at its rated overall watts.
14,000–3,800	380
3,800–3,100	180
3,100–1,850	300

Waco Separators

The Waco Separators, manufactured by the *Wilkens-Anderson Company, 111 North Canal Street, Chicago,* save time and equipment. A ten-second spin, at full speed, precipitates the solid to the bottom of the tube; the liquid is decanted and the solid washed.

The smooth aluminum head has no dangerous flying tube holders. The mechanism is silent. The separators are built for long service. The 110-volt A.C. separator has the Waco new ribbed shell, brushless induction motor, which eliminates sparking.

Stainless Steel Thermometer for Laboratory Use

An entirely new type of laboratory thermometer, provided with a dial-and-pointer scale encased in stainless steel, mounted on top of an 8-inch stainless steel stem, is being introduced by the *Weston Electrical Instrument Corporation, Newark, New Jersey.*

The unit is said to be the first dial-type thermometer with an all-metal temperature element sufficiently accurate for scientific use. The pointer is actuated by means of an internally balanced double coil of thermostatic bimetal sealed in the lower one and one-half inches of the seamless stem. When the stem is immersed to a depth of one and one-half inches in a liquid (three inches in gas or vapor), the dial reads temperature values accurately without the necessity for stem correction.

Accuracy of the unit is guaranteed to one-half of one-per cent. over the entire scale. In practice, the location of the dial at the top of the stem, removed from the liquids or vapors under measurement, encourages a further increase in the accuracy with which readings are made. Dial markings are spaced for maximum readability on the metal scale plate, and are not subjected to obliteration from the solutions under test, as is the case with stem gradations. The low temperature values are not obscured in dark-viscous solutions.

The unit is extremely rugged and completely corrosion-proof to all but a very few laboratory reagents. Construction of the temperature-sensitive coil is also inherently rugged and shock-proof. Reasonable overrange temperatures will not affect the accuracy of the unit.

Initial models of the unit are being offered in the following scale ranges: 0–220°F., 50–300°F., 50–500°F., 0–100°C., 0–150°C. Applications include temperature measurement in educational and industrial research laboratories, in control laboratories, hospitals, and general scientific use.

New Du Pont Dyestuffs

Four new dyestuffs are announced by *E. I. du Pont de Nemours,* designed for application in the textile, printing ink, and lacquer industries.

"Sulfogene" Bordeaux 2RN is the brightest and bluest sulfur bordeaux *du Pont* has yet developed. A textile color, it may be applied as a self-color but is more generally employed in combination as a reddening and brightening element.

"Sulfogene" Direct Blue 2RCF (Patent Applied For) yields bright, reddish shades of navy blue. It is a direct-dying, non-bronzing blue, suited to dyeing pieces in the jig. It will be used both alone and as a base for navy blues on materials which must withstand hard wear, such as overalls, ducks, and drills.

"Lithosol" Fast Yellow HL Powder is a lake color yielding bright medium shades of yellow, developed for use in printing inks, water paints, and lacquers. A pigment requiring no precipitating agent when mixed with or thrown on basis, it has demonstrated good tinctorial strength and working properties. The new color is slightly greener and brighter in shade and somewhat darker in masstone than "Lithosol" Fast Yellow HN Powder, to which it is chemically akin.

"Lithosol" Scarlet 2YL, designed for printing inks and lacquers, has a deep masstone and yellow tint, and, when used as a strontium toner, closely resembles du Pont Scarlet 2R for Lakes in shade. The barium toner is much lighter in masstone and yellower in shade than in strontium type, while the calcium salt is very blue in shade and slightly yellower in masstone. The outstanding fastness characteristic of Scarlet 2YL is its resistance to light.